Eos, Transactions, American Geophysical Union Vol. 65, No. 31, Pages 457–464 July 31, 1984

Particles and Fields—Ionosphere

5505 Airglow
ROCKET OBSERVATIONS OF THE ULTRAVIOLET AIRGLOW DURING MORNING TWILIGHT
S. P. Cebula and P. D. Feldman (Physics Department, Johns Hopkins University, Baltimore, Maryland 21218
The nitric oxide γ- and δ-bands, OII λ2470, OI 1113SS and 1304 lines, and N_2 LBH and O_2 Herzberg band emissions were observed during morning twilight between 90 and 246 km on 24 September 1979 with two rocket-borne scanning monochromators viewing successively at 82° and 90° to the zenith near the sun-earth-rocket plane. The solar zenith angle was 110°. The relative intensities of the two nitric oxide band systems suggests that the observed emission is primarily due to resonance fluorescence along the sunlit portion of the rocket line-of-sight, with the chemiluminescence contribution greatly reduced from that observed during evening twilight. The densities at 200 km derived from the observed emission rates are 4 x 10^{8} cm^{-3} for NO and 5 x 10^{6} cm^{-3} for $N(^4S)$, consistent with recent odd nitrogen models which predict a much greater nighttime decrease of $N(^4S)$ than of NO. The atomic and ionic oxygen emissions are modelled in a self-consistent way based on direct photoionization and photoelectron impact ionization. The atomic oxygen density near 190 km is derived from O_2 Herzberg 1 band emission observed near the end of the flight. (Ultraviolet, airglow, twilight).

J. Geophys. Res., A, Paper 4A0926

6560 Particle precipitation
DIURNAL VARIATION OF BURST PRECIPITATION EFFECTS ON SUBIONOSPHERIC VLF/LF SIGNAL PROPAGATION NEAR L=2
T. B. Leyser, U. S. Inan, D. L. Carpenter, M. L. Trimpi (Space, Telecommunications and Radioscience Laboratory, Stanford University, Stanford, California 94305)
Burst precipitation effects on subionospheric VLF/LF signal propagation are studied using data recorded at Palmer Station, Antarctica (L~2.4) between March 3 and April 7, 1983. Relatively abrupt signal amplitude changes, known as "Trimpi" effects, were observed in conjunction with magnetospheric whistlers, which are inferred to induce electron precipitation that in turn causes enhanced ionization at the 80-90 km altitude level. Earlier findings that Trimpi effects occur predominantly under nighttime ionospheric conditions were confirmed by comparing the sunrise-sunset terminator position with perturbation activity on three VLF/LF signal paths for which the arrival bearings range from magnetic north to west. Events were found to occur on 70% of the observing nights. Signal paths making larger angles with the terminator were used to deduce that most events were caused by ionospheric effects occurring within ~1,000 km of Palmer Station. Some events were observed after sunrise over the observing station, apparently due to precipitation in dark regions as far as ~1,800 km away. Observed differences between two different paths in the occurrence of this post-sunrise explanation of Trimpi events suggest that the Trimpi event activity rate decreases below L~2. This may be due to a reduction in whistler activity and/or lower particle scattering efficiency. The average hourly occurrence rate of NSS events on the 11 most active nights studied increased from sunset to near midnight and then remained at a roughly constant level until sunrise. The influence of the whistler rate and of whistler path locations on Trimpi effects is clearly important, and requires further study. (Particle precipitation, whistlers, ionospheric effects)

J. Geophys. Res., A, Paper 4A0859

6560 Particle Precipitation
MORPHOLOGY OF THE POLAR RAIN
M. S. Gussenhoven (Space Physics Division, Air Force Geophysics Laboratory, Hanscom AFB, MA 01731), D. A. Hardy, N. Heinemann and R. K. Burkhardt
Results of a statistical study of the occurrence and characteristics of the polar rain (Winningham and Heikkila, 1974) are reported. Precipitating electron data in the energy range from 50 eV to 20 keV from the SSJ/3 sensor on the polar orbiting DMSP/F2 satellite were used for the study. Intervals of clear polar rain were identified in all orbits in the one-year interval, September, 1977 to August, 1978. The spectra from the intervals were binned in a two-dimensional spatial array in geomagnetic latitude and magnetic local time. Separate arrays were maintained for different levels of magnetic activity, values of the components of the interplanetary magnetic field (IMF) and season. The average spectra were determined in each bin, and were used to calculate the integral flux and average energy. Two dimensional maps of average energy and integral flux show significant large-scale spatial variations that are roughly symmetric about an axis running pre-noon to pre-midnight. Integral flux (average energy) decreases (increases) from the dayside to the nightside along this axis by a factor of almost 16 (3). This basic variation was maintained in all separations by magnetic activity, season, intensity of the polar rain and sector structure, although small rotations in magnetic local time of the symmetry axis could be seen in some cases. The second most prominent variation is one that has been noted previously (Yeager and Frank, 1976; Meng and Kroehl, 1977); polar rain occurs preferentially in the northern (southern) cap for away (toward) IMF sectors. In the preferred cap the precipitation is stronger in the morning. Approximately 70% of the spectra occurred for Bz-negative. The overall intensity of the polar rain increases and cools with increasing magnetic activity. The occurrence of polar rain falls within a circular region whose center is offset toward pre-midnight and whose radius increases with magnetic activity. (Electron precipitation, polar cap).

J. Geophys. Res., A, Paper 4A8168

5585 Plasma motion, convection, or circulation
B_y-DEPENDENT CONVECTION PATTERNS DURING NORTHWARD IMF
T. A. Potemra (Johns Hopkins University, Applied Physics Laboratory, Laurel, Maryland, 20707), L. J. Zanetti, P. F. Bythrow, A. T. Y. Lui and T. Iijima
Observations of Birkeland currents, electric fields, and auroral forms in the day side polar regions during periods of northward interplanetary magnetic field (IMF) can be unified to fit into consistent convection patterns ordered principally by the IMF B_y component. During periods of weak IMF B_y, two polar convection cells are symmetrically located on either side of the noon-midnight meridian, producing sunward convection over the pole, as previously reported. As the IMF B_y becomes significantly positive (negative), the dawn (dusk) convection cell expands across the northern polar cap, whereas the other cell shrinks. In the southern polar cap, it is the dusk (dawn) cell which expands. During strong B_y, this cell expansion gives the appearance of a single convection cell in the polar region. At the "collapsed" cell, a large convection flow gradient is developed where reversal of the NBZ Birkeland current system, tail-maneuvered polar ionospheric current, and the enhanced polar cap electric fields are statistically observed. We suggest that this convection gradient region is also associated with sun-aligned arcs and the transpolar arc of the theta aurora, which are observed in the polar regions during northward IMF. The convection patterns proposed here are consistent with the anti-parallel merging model in which the IMF merges with the open geomagnetic field lines to the tail lobe during northward IMF intervals. The resulting convection in the tail brings plasma from the plasma sheet to the tail. This process divides the open field lines of the lobes and produces an area of closed field lines in the polar cap associated with the transpolar arc of the theta aurora.

J. Geophys. Res., A, Paper 4A8117

5563 Plasma motion, Convection, or Circulation
THE IMPORTANCE OF VERTICAL ION CURRENTS ON THE NIGHT-TIME IONIZATION IN THE EQUATORIAL ELECTROJET
S. Raghavarao (Physical Research Laboratory, Ahmedabad, India, 380 009), R. Sridharan and R. Sekar
The equatorial electrojet region plasma density at 100 km increases by a factor of 2 to 10 from the time of sunset to midnight. In addition a valley in the plasma density centered around 120 km altitude deepens by a factor of 2 to 5 during the same period. These, so far unexplained features are explained on the basis of the dynamical processes peculiar to the electrojet region. By solving the time dependent continuity equation for the most dominant ion viz. NO^+ the importance of the vertical transport of ionization has been brought out. The production of ionization due to scattered EUV radiation though plays the role of maintaining the basic ionization level, it is the vertically downward motion of positive ions due to the Pedersen currents that redistributes the nighttime ionization and enhances the density at 100 km. The valley in the density is shown to be formed at 120 km where the vertical ion velocity maximizes. (Vertical ion currents, electric fields, redistribution of ionization).

J. Geophys. Res., A, Paper 4A8037

5570 Total electron content
EAST-WEST PLASMA BUBBLE IRREGULARITY MOTION DETERMINED FROM SPACED VHF POLARIMETERS: IMPLICATIONS ON VELOCITY SHEAR IN THE ZONAL F-REGION BULK PLASMA MOTION
M. A. Abdu (Instituto de Pesquisas Espaciais - INPE, Conselho Nacional de Desenvolvimento Científico e Tecnológico - CNPq, 12200 São José dos Campos, S.P., Brazil), I. J. Kantor, I. S. Batista and E. R. de Paula
VHF electronic polarimeters were used to monitor Faraday rotation angle and amplitude of geostationary satellite (GOES-3) beacon signals, simultaneously at two stations, Cachoeira Paulista (22°41'S, 45°00'W) and São José dos Campos (23°12'S, 45°53'W), separated by 110km exactly in the magnetic East-West direction in Brazil. The analysis of the data for a few months in 1981-82 period, carried out in this paper, shows TEC fluctuations correlated with range type spread F events in the local ionograms and amplitude scintillations in the satellite beacon signals, thereby identifying themselves as plasma bubbles and associated structures in the equatorial ionosphere. The spaced polarimeter system has permitted determination of the East-West velocities of these plasma bubble structures whose nighttime pattern is in excellent agreement with those of the eastward bulk plasma measured by Jicamarca radar and with those of the plasma bubble irregularities obtained from different radio and optical measurements carried out in the equatorial and low latitude regions. There exist, however, significant differences in the magnitude of the velocities in the different measurements, our results over low latitude showing highest values of all. These differences are interpreted as suggesting the possibility of a latitudinal variation in the plasma zonal velocities, consistent with the already known existence of vertical shears in the bulk plasma zonal flow over the equator. (Polarimetric TEC fluctuations, Spread F, East-West plasma bubble velocities).

Rad. Sci., Paper 4S0921

News

Oregon Seismic Experiment

The United States Geological Survey (USGS), with support from the Geothermal and Hydropower Technologies Division of the U.S. Department of Energy, will be conducting an active seismic experiment in central Oregon using nine large explosions during the last week of August 1984. A major goal of this experiment is to detect kilometer-size magma chambers in the upper crust below Newberry Volcano (Figure 1). The planned experiment is a small-scale version of one type of seismic-imaging experiment proposed by the Program for Array Seismic Studies of the Continental Lithosphere (PASSCL). Because of the required density of the recording array, the USGS recording effort will be concentrated in and around the summit caldera and leave ample opportunity for additional recording of the large shots by interested parties, to study the rest of the volcano and surrounding geologic provinces.

Newberry Volcano is situated in central Oregon 50 km east of the High Cascade Range axis at the intersection of several major geologic provinces (Figure 1). Rhyolites of Newberry Volcano are the northwestern, young end members of a westward progression of rhyolitic volcanism which has occurred in south-central Oregon during the past 10 m.y. MacLeod and Sammel (*Calif. Geol., 35*, 235–244, 1982) presented an excellent description of the geology of Newberry Volcano, from which the following brief description is abstracted. The volcano is a broad shield, about 1 km high and covering an area of 1,200 km². The flanks are veneered by hundreds of basalt and basaltic-andesite flows and cinder cones with carbon 14 ages as young as 5,800 years. A caldera, 6–8 km in diameter, is present at the summit; the recent volcanism inside this caldera, in contrast to the mafic volcanism on the flanks, is predominantly rhyolitic. The most recent rhyolitic volcanism occurred 1,350 years ago. The occurrence of young silicic volcanism and hot springs in the summit caldera makes Newberry Volcano a prime target for geothermal exploration. Drilling within the caldera has been conducted by the USGS and Sandia National Laboratories. Similar temperature profiles were determined in both holes, and a temperature of 265°C was measured at the bottom of the USGS hole at a depth of 932 m (MacLeod and Sammel, *Calif. Geol., 35*, 235–244, 1982). This high temperature and the occurence of young silicic volcanism suggest the existence of magma chambers within the shallow crust below the summit of the volcano.

Several seismic experiments have been conducted by the USGS in the vicinity of Newberry Volcano, including a teleseismic *P* residual study of the volcano, and two seismic-refraction lines. The teleseismic *P* residual study detected a column of high *P* velocity material, about 15 km in diameter, extending from within 10 km of the surface to 25 km depth beneath the summit, which is interpreted to result from numerous subsolidus mafic intrusions. One of the seismic-refraction lines runs along the margin of the High Cascade and Western Cascade provinces (Figure 1) and the results have been published by Leaver, Mooney, and Kohler (*J. Geophys. Res., 89*, 3121–3134, May 1984). The other seismic-refraction line which runs east-west through Newberry Volcano (Figure 1) was shot in fall 1983 as preliminary work for the current USGS experiment. A station spacing of 0.5 km and a shotpoint spacing of 15.0 km were used to allow concentration of a detailed seismic-velocity cross section of the volcano. Interpretation of this refraction line is in progress.

The upcoming USGS experiment is similar to that performed at Le Mont-Dore Volcano, France, by Nercessian, Hirn, and Tarantola (*Geophys. J. R. Astron. Soc., 76*, 307–315, 1984). *P* waves, generated by explosions distant from the volcano and reflected or refracted back toward the surface by the crustal velocity structure, will be used to illuminate, from below, the summit region of Newberry Volcano from many azimuths. The receiving array will consist of 120 portable analog recorders normally used in USGS refraction work and will cover a region, about 12 km in diameter, centered on the summit caldera, with an average station spacing of 1 km. Traveltime residuals will be inverted to obtain a three-dimensional *P* velocity model to a depth of about 5 km, with a spatial resolution of about 1 km. The distances from the array to the shot points were selected, after partial analysis of the detailed east-west refraction line through Newberry Volcano, to use two coherent impulsive and high-amplitude phases. Figure 2 illustrates ray paths for these two phases. Nine shot points are located at these two distances with as uniform an azimuthal distribution as possible (Figure 1). Here, 2,700 kg of explosives will be detonated below the surface at each shot point at scheduled times divided between two nights.

Because of the large number and sizes of the planned shots, many opportunities exist for recording reversed and unreversed refraction profiles (which will not be covered by the USGS) on Newberry Volcano and in the adjacent provinces, including the High Cascade Range, the Basin and Range, and the High Lava plains. Persons interested in utilizing these planned shots for such experiments should contact the author to obtain more information about the shots, the exact schedule, and possible coordination with other interested parties.

This news item was contributed by Douglas Stauber of the U.S. Geological Survey in Menlo Park, Calif.

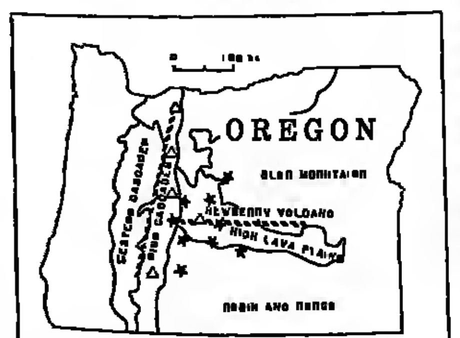

Fig. 1. Oregon, showing physiographic provinces (Baldwin, *Geology of Oregon*, 147 pp., 1976), major Cascade Range volcanos, including Newberry Volcano (triangles), existing USGS refraction lines (heavy-dashed lines), and planned shots (stars).

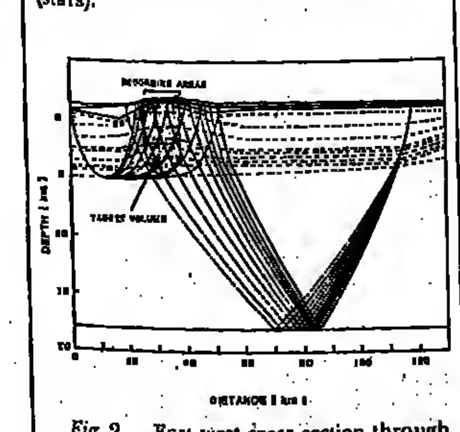

Fig. 2. East-west cross section through Newberry Volcano, showing ray paths for two phases to be used in the USGS experiment.

Upcoming Hearings In Congress

The following markup and conference committee have been tentatively scheduled by the Senate and House of Representatives. Dates and times should be verified with the committee or subcommittee holding the markup or conference; all offices on Capitol Hill may be reached by telephoning 202-224-3121. For guidelines on contacting a member of Congress, see *AGU's Guide to Legislative Information and Contacts* (*Eos*, April 17, 1984, p. 159).

August 7: Mark up legislation that would require federal Coastal Zone Management plans to be consistent with state management plans (H.R. 4589) by the House Merchant Marine and Fisheries Committee. Longworth Building, Room 1334, 10 A.M.

August 8: Conference on ocean and coastal resources block grants for fisheries programs and deep seabed minerals resources programs (S. 2463). Capitol Building, Room S205, time to be announced. (Note new date.)—*BTR*

Wind Shear Test

Techniques for forecasting and detecting a type of wind shear called microbursts are being tested this month in an operational program at Denver's Stapleton International Airport as part of an effort to reduce hazards to airplanes and passengers.

Wind shear, which can be spawned by convective storms, can occur as a microburst. These downbursts of cool air are usually recognizable as a visible rain shaft beneath a thundercloud. Sometimes, however, the rain shaft evaporates before reaching the ground, leaving the downdraft invisible. Although thunderstorms are traditionally avoided by airplane pilots, these invisible downdrafts also harbor hazards in what usually appear to be safe skies. When the downdraft reaches the earth's surface, the downdraft spreads out horizontally, much like a stream of water gushing from a garden hose on a concrete surface, explained John McCarthy, director of the operational program. Airplanes can encounter trouble when the downdraft from the microburst causes sudden shifts in wind direction, which may reduce lift on the wing, an especially dangerous situation during takeoff.

The test at Stapleton, funded by the Federal Aviation Administration, is dubbed CLAWS: Classify, Locate, Avoid Wind Shear. The operational program aims to develop procedures for using the information that Doppler radars can provide, establish the validity of microburst forecast techniques, and provide airplane pilots with the necessary real-time information.

CLAWS is the "natural consequence of the Joint Airport Weather Studies (JAWS) field research that took place at Stapleton during the summer of 1982 and our analysis of those findings," said McCarthy, who also directed JAWS. "It is vital for us to test our ultimate ability to transfer this information to the air traffic controllers who will, in turn, advise the pilots."

JAWS was designed by the National Center for Atmospheric Research (NCAR) and the University of Chicago.

Bullard Fellowship

A research fellowship honoring the late Sir Edward Bullard has been established in his name at Churchill College in Cambridge, England.

Bullard received the AGU Maurice Ewing Medal in 1978 and the AGU Bowie Medal in 1975. His work was most recently described in *Eos* by Elizabeth N. Shor (*Eos*, February 28, 1984, p. 73). Bullard died April 3, 1980.

AGU members who would like to contribute to the fellowship are invited to do so through the American Friends of Cambridge University, P.O. Box 7070, Arlington, VA 22207. Please be sure to clearly identify all gifts as a contribution to the Bullard Research Fellowship. AFCU is a registered non-profit, charitable organization; contributions are deductible for U.S. tax purposes.

Milky Way Gas

An enormous arc of hot gas protruding from the center of our galaxy has been discovered by astronomers near the center of the Milky Way. The existence of the arc could mean that stars are not being formed there at the high rate previously assumed. This assumption had been made because of the intense radio emissions rising there.

Discovered using the National Radio Astronomy Observatory's Very Large Array (VLA) in New Mexico, the structure resembles a solar prominence, which is a great streamer or column of glowing gas that often rises to great heights at enormous velocities above the sun's surface. The arc is 150 light years long and 30,000 light years from the earth.

"Among the unique characteristics of this unparalleled structure is its coherent organization on such a large scale, suggesting that its presence is linked to the structure of our galaxy," according to astronomer Mark Morris of the University of California at Los Angeles. Also on the research team making the discovery are Farhad Yusef-Zadah and Don Chance, both from Columbia University.

"The evidence now available, especially the detailed shape of the structure, implies that the arc of hot ionized gas is controlled by a magnetic field," Morris added. "While our galaxy has been known for some time to contain a magnetic field, this is the first indication of the existence of a substantial poloidal magnetic field, a field akin to the dipole field of a simple bar magnet."

Dipole magnetic fields are present in the earth, the sun, and other stars, and in some planets of the solar system. Such fields are theoretically understood in terms of a dynamo mechanism that generates them in a manner related to the way in which commercial electricity is generated by electric dynamos. If the analysis holds, Morris said, the new discovery may be revealing the existence of a galactic dynamo.

"The importance of understanding the activity in our galactic nucleus lies in what it may imply about the much more intense activity seen in the nuclei of radio galaxies, quasars, and other varieties of active galaxies," the astronomer said.

Geophysicists

Otis B. Brown has been appointed acting chairman of the division of meteorology and physical oceanography at the University of Miami's Rosenstiel School of Marine and Atmospheric Science. Brown succeeds ***Friedrich Schott***, who was chairman since 1979.

Mark Carle and ***Christopher G.A. Harrison*** of the Rosenstiel School of Marine and Atmospheric Science were commended recently by the National Aeronautics and Space Administration (NASA) for scientific use of scientific data. Each has studied the magnetic field over the ocean basins with data collected by the MAGSAT satellite. The commendation was presented by ***Gilbert Ousley***, leader of the NASA team responsible for the design, construction, and operation of MAGSAT.

Moustafa T. Chahine has been appointed as Chief Scientist of the Jet Propulsion Laboratory (JPL). He succeeds ***Arden Albee***, who will return at the end of August to his faculty position in the Division of Geological and Planetary Sciences at the California Institute of Technology. Chahine joined JPL in 1960 as a senior scientist specializing in atmospheric studies. He is currently manager of JPL's Earth and Space Sciences Division.

William S. Gaither, founder and dean of the College of Marine Studies at the University of Delaware, was selected as Drexel University's next president at the university's board of trustees meeting in May.

The Oceanography Report

H.M.S. CHALLENGER PREPARING TO SAIL, 1872

Editor: David A. Brooks, Department of Oceanography, Texas A&M University, College Station, TX 77843 (telephone: 409-845-5527).

New Directions For The National Ocean Service

Paul M. Wolff

The National Ocean Service, which I've headed since December 1983, is one of the major line components of the National Oceanic and Atmospheric Administration (NOAA). NOAA, in turn, is part of the Department of Commerce and is the leading federal agency in the oceanic and atmospheric sciences. Other agencies are involved in the earth sciences, such as the Department of the Interior's Geological Survey, or are in the business of environmental regulations, like the U. S. Environmental Protection Agency, but NOAA is the one federal agency charged specifically with analyzing and predicting oceanic and atmospheric components of the earth's environment as a whole. The importance of this global, integrated air-sea approach is reflected in the five NOAA line offices.

This past December, NOAA line offices were reorganized to consolidate programs as part of the Reagan Administration's general government-wide belt tightening (see Figure 1). The idea was for NOAA to grow leaner but stronger. The main thrust of the work of the Weather Service and the Marine Fisheries Service remained the same. The Office of Oceanic and Atmospheric Research continued to provide research support to the other NOAA components. A trimmed down Environmental Data and Information Service merged with the National Environmental Satellite Service to become today's National Environmental Satellite, Data, and Information Service. Also, this past December the NOAA Office of Coastal Zone Management joined forces with the National Ocean Survey to become the National Ocean Service.

This change from Ocean Survey to Ocean Service was more than just a name change; it gives a clue to other changes and new directions for NOAA in general and the National Ocean Service in particular. What is being done throughout the NOAA team is to emphasize "service," to make NOAA products and services more responsive to the needs of users. Right now, the National Ocean Service and other NOAA components are re-evaluating many traditional products and services and are taking on some new responsibilities that build on existing NOAA capabilities and expertise.

Today's National Ocean Service is made up of four line offices that carry out its major functions: charting and geodetic services, oceanography and marine services, ocean and coastal resource management, and marine operations. (Since this article was written, the National Ocean Service has further realigned its programs to improve products and services by creating a new line office solely responsible for ocean services and external affairs.) (See Figure 2.)

The Office of Charting and Geodetic Services produces NOAA's nautical and aeronautical charts, special purpose marine maps, and geodetic products and services. This is the heart of the Ocean Service's predecessor agencies, since the agency was founded in 1807 during the administration of Thomas Jefferson to survey and chart the Atlantic coastal waters of the new republic. Working closely with other NOAA and Ocean Service offices, the Office of Charting and Geodetic Services will have a lead role in surveying the 200-mile Exclusive Economic Zone (EEZ) that President Reagan declared in March of 1983. The EEZ Proclamation "confirms U.S. sovereign rights and control over the living and non-living natural resources of the seabed, subsoil and superadjacent waters beyond the territorial sea but within 200 nautical miles." National Ocean Service responsibilities will include in-depth and comprehensive physical, biological, and chemical assessments. This is a massive job that will change many of the ways NOAA surveys and makes observations. In addition to the hydrographic surveys NOAA conducts by ship, it will be necessary to greatly increase the use of both fixed and floating platforms, including those designed specifically for ocean observations and commercial platforms intended for other purposes, such as oil and gas exploration. The goal is to double the amount of marine observations in a year and to increase them 10 times over the next 5 years.

The Office of Ocean and Coastal Resource Management is the part of NOAA that was added to the old National Ocean Survey to make the new National Ocean Service. Through this office, NOAA provides the coordination and expertise at the federal level needed to balance the often competing demands to preserve and to develop the marine resources within the U.S. coastal zone. This office works closely with coastal states, and as these various states win approval for their coastal zone management plans and develop their own coastal programs, involvement at the federal level will be phased out.

The Office of Marine Operations is the Ocean Service component that manages and operates NOAA's fleet of research and survey ships, which collect basic marine data used by all the other NOAA components. Since ships and time at sea are very expensive, this is one area in which NOAA is trying especially to improve productivity and efficiency. One way to achieve these goals is to share ship time with other federal and state agencies, universities, research organizations, and other groups and individuals in the private sector. This piggy-backing of experiments and multiple-use cruises result in more economical use of NOAA ship time, while at the same time improving the productivity of individual cruises. NOAA is also installing new equipment on the NOAA ships, including Global Positioning System receivers, SEAS transmitters to relay meterological data directly to the Weather Service for processing, multi-beam sensors, new CTD profilers, and perhaps most important, a new automated hydrographic data acquisition and processing system called the Shipboard Data System (SDS) III. SDS III is replacing the mainstay hydrographic data acquisition and processing system of the NOAA Fleet, the Hydrolog/Hydroplot System. Hydrolog/Hydroplot is based on the Digital Equipment Corporation's PDP-8/e computer, one of the earliest minicomputers. One of the biggest problems faced by NOAA in recent years was that the NOAA ships were able to collect much more data than could be processed expeditiously. This resulted in a huge data backlog that NOAA is now vigorously trying to reduce. The goal is to eliminate existing backlogs and establish systems to complete data processing end-to-end within 60 days of the time the data are received from ships or other sources.

The Office of Oceanography and Marine Services is one of the newest line elements of the National Ocean Service. Whereas today it is one of NOAA's busiest line offices, only a few years ago it was only a division of a line office. This expansion in NOAA oceanographic programs probably best reflects one of the new directions that line offices are moving in throughout NOAA. Through the Office of Oceanography and Marine Services, NOAA collects, processes, and analyzes a wide range of data and information that describe the physical processes of the oceans, the U.S. coastal zone, estuarine waterways, and the Great Lakes. But whereas the Ocean Service formerly collected these types of hydrographic data primarily to support in-house charting and surveying functions, the engineering and coastal management uses of these observations have now become just as important. The National Ocean Service still produces tide predictions, tidal current predictions, tidal current charts, and other traditional data products that are primarily nautical-chart related. But greater emphasis is now being placed on oceanographic and marine information products that provide the scientific basis for offshore oil and gas exploration, dredging operations, coastal and offshore construction, emergency planning programs of coastal communities, and other engineering applications. There now is also an entire division within the Office of Oceanography and Marine Services to conduct assessments of the multiple uses of marine resources and project the impacts of these activities on the environment. A major goal here is to establish baseline environmental conditions so that it is then possible to determine trends in the ocean environment.

Another new, major NOAA program that plays a crucial role in improving NOAA's delivery of oceanographic and marine products and services is the concept of regional NOAA ocean service centers. This past October NOAA opened the first of these centers in Seattle, Wash. This prototype center is the first in a proposed network of one-stop retail service centers, staffed by personnel from each NOAA component, where users of NOAA's oceanographic products and services in individual regions of the United States can go to get needed information that NOAA provides. The Northwest Ocean Service Center and the others planned by NOAA will be a place where users of NOAA products can go to tell representatives of each NOAA line office what is good about NOAA ocean products and services, what is bad about them, what NOAA is doing right, and what NOAA is doing wrong. (See Figure 3.)

The goal of all of this, from the upgrading of NOAA's research and survey ships to the establishment of regional NOAA ocean service centers, is to provide products and services that better meet the needs of users, turn out these products and services more efficiently, and improve the turnaround time for their delivery, the essence of the new directions for NOAA and for the National Ocean Service. (See Figure 4.)

Paul M. Wolff is Assistant Administrator, NOAA, Washington, D.C. This paper is a condensed version of a presentation made at the Ocean Science luncheon at the 1984 AGU Spring Meeting, May 16, 1984.

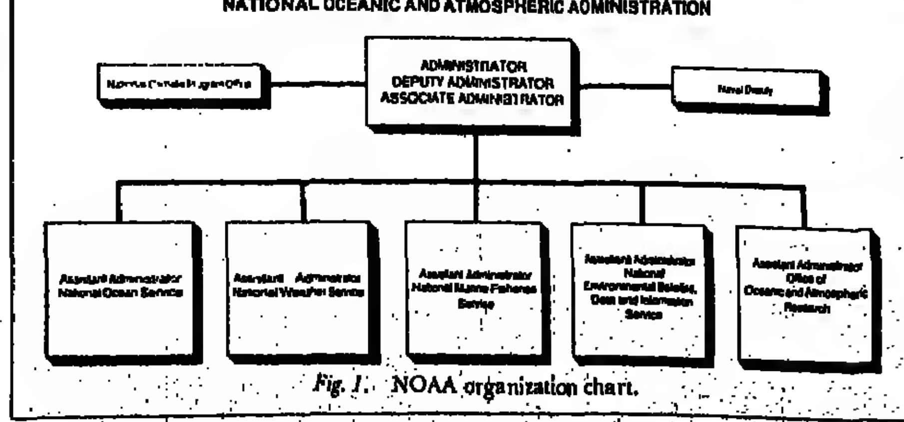

Fig. 1. NOAA organization chart.

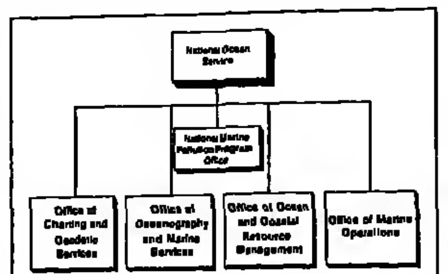

Fig. 2. National Ocean Service organization chart.

PROGRAM OBJECTIVES

- PROVIDE USER-ORIENTED OCEAN SERVICES
- MODERNIZE INSTRUMENTATION
- INCREASE COOPERATION WITHIN GOVERNMENT AND WITH THE PRIVATE SECTOR
- INCREASE EFFICIENCY OF VESSEL USE
- ORGANIZE AND CONDUCT INTENSIVE SURVEYS OF THE EXCLUSIVE ECONOMIC ZONE
- DETERMINE BASELINE STATUS AND TRENDS OF OCEAN ENVIRONMENT

Fig. 3. Program objectives.

ACCOMPLISHMENTS BY END OF FY 1986

- ESTABLISHED AND OPERATING NATIONAL OCEAN SERVICE CENTER NETWORK AND SUPPORTING PROCESSING CENTERS
- MODERNIZED AND EXPANDED OBSERVATION CAPABILITIES FOR NOAA FLEET
- SIGNIFICANTLY INCREASED USE OF NOAA FLEET WITH OTHER FEDERAL AGENCIES AND USERS
- REPLACED OUTMODED DATA ACQUISITION AND PROCESSING SYSTEMS
- ELIMINATE DATA BACKLOGS AND ACHIEVED 60 - 90 DAY PROCESSING AND AVAILABILITY TIMES

Fig. 4. Accomplishments by end of fiscal year 1986.

Information Report

Ocean Climate Research

A recently published report, *An Ocean Climate Research Strategy* [*Webster*, 1984] reviews ocean research that will lead to or support an ability to predict year-to-year natural variations in climate one season in advance. The study was supported by the National Science Foundation (NSF) and is intended to guide NSF in its lead role for ocean climate research. This article summarizes that study. As with the original report, I here give my personal conclusions derived from the review. Copies of *An Ocean Climate Research Strategy* are available from the Board of Atmospheric Sciences and Climate, National Research Council, 2101 Constitution Avenue, Washington, DC 20418.

Summary

Oceanographers and meteorologists have proposed research programs to enhance our understanding of climate variability [*Committee on Climatic Changes and the Oceans*, 1983a; *Board on Ocean Science and Policy*, 1983]. Parts of these programs are already under way. The report reviews proposals for two large-scale research programs: the Interannual Variability of the Tropical Ocean and the Global Atmosphere (TOGA) and the World Ocean Circulation Experiment (WOCE). In addition, it reviews plans for large-scale ocean heat flux experiments, ocean climate monitoring, and ocean climate research that are not explicitly included in the existing proposals for large-scale experiments. The report offers advice on strategies for use by NSF.

NSF is the lead federal agency for the Ocean Heat Transport and Storage "principal thrust" of the National Climate Program. The National Climate Program Plan [*U.S. National Climate Program Office*, 1980] designates six principal thrusts, two of which deal with research. A principal thrust has high priority, is of major importance to the goals of the program, and promises significant opportunity for progress. The report considers where ocean climate research supported by each agency might fit into the national program.

Finally, the report considers the international setting. Many countries are participating in the planning of a global research program that addresses all aspects of the problem of climate: the World Climate Research Program (WCRP). The report reviews WCRP plans and advises on how American ocean climate research activities can fit within the world program, can aid it, and can benefit from it.

Role of the Ocean in Climate Variability

What are the mechanisms, if any, by which the ocean influences year-to-year variations in the earth's climate? Does the ocean play a role in producing climate anomalies, such as droughts, floods, heat waves, and abnormal frosts? If it does, can we understand the processes whereby this occurs? Can we develop a capability for predicting climate change?

We know that the ocean plays a major role in determining the mean climate state of the world. It is critical in controlling global patterns of precipitation and evaporation. The ocean absorbs energy from the sun and releases energy to the atmosphere at times and places distant from the point where the energy was received. The seasonal temperature range is reduced over land areas adjacent to the ocean because of the large heat inertia of the ocean.

The oceanic poleward flux of heat is of the same order of magnitude as the atmospheric, but the processes of oceanic transport are not well understood. To understand the mean climate state of the world, we must take account of the role of the ocean in establishing and maintaining the global heat balance. However, the mean climate state of the ocean is not well understood. Unless oceanic variability can be defined in terms of its departure from some mean state, we may be unable to explain the influence of the ocean on global climate.

Both ocean and atmosphere show climate variability on time scales of months to centuries. The annual or seasonal cycle is generally large, but the nonseasonal variability can exceed the seasonal, particularly in some oceanic areas. Ocean heat storage, transport, and transfer to the atmosphere are variable. It may be that such variations are the principal oceanic factor controlling climate variability. Thus an understanding of the uptake, transport, storage, and release of heat by the ocean may lead to an understanding of global climate variations.

Models of the atmosphere with and without a moving ocean show that the ocean influences the mean atmospheric temperature distribution. The circulation of the ocean appears to affect climate variability on all scales. Thus there are proposals to study the general circulation and the climate state of the ocean.

Ocean heat transport and storage processes have lifetimes that are long in comparison with those of the atmosphere. Atmospheric predictability may be limited to week or two. But the chain of events in the Southern Oscillation, a global-scale atmospheric and oceanic climate anomaly, has a duration of about 18 months. Though the ocean and atmosphere interact, this long time scale seems to be dominated by the high thermal and mechanical inertia of the ocean. Thus, long-range climate forecasting probably must take ocean processes into account.

The largest nonseasonal climate variation is the interannual, which may regionally be larger than the annual or seasonal. Year-to-year variations in the earth's climate are of great economic importance. Unusual rainfall, drought, or heat waves can have significant agricultural impacts. Oceanic thermal variations related to climate variability can affect marine fisheries. Thus, there are economic incentives to develop a predictive ability.

Climate variations having scales of approximately a decade, with important economic effects, are known to exist but are less well documented than those of annual time scale. There is evidence that the ocean plays a role in decadal climate variability, and some proposals for large-scale ocean experiments to understand decadal variability have been made. The consensus seems to be that to develop a predictive capability, research on interannual climate phenomena should have first priority. At this time, no plans for ocean studies explicitly directed to decadal climate scales have emerged in the World Climate Research Program.

Long-period climate variability, having time scales between decades and centuries, is not well documented [*Hecht*, 1981]. The study of such phenomena obviously requires a long-term commitment. The economic impact is uncertain. It is even unclear how to make use knowledge of long-term climatic variation if it were available.

Interannual Variability of the Tropical Ocean and the Global Atmosphere

The Southern Oscillation, a family of naturally occurring, interacting phenomena in the ocean and atmosphere that produces climate anomalies, provides an opportunity to carry out experiments in interannual climate forecasting and to develop a climate prediction capability. The phenomena that make up the Southern Oscillation (e.g., anomalies of sea-surface temperature, atmospheric pressure, precipitation, and temperature) are found in the tropical ocean and global atmosphere. In addition, some component processes of the Southern Oscillation, centered in the Pacific Ocean, may have analogues in the other tropical oceans. A study of these phenomena, their properties, their linkages, and their climate consequences holds promise of providing a predictive capability that far exceeds what can be achieved through atmospheric studies alone.

The Southern Oscillation is a large-scale exchange of atmospheric mass in the atmosphere between the eastern and western hemispheres in the tropics. It can be detected in sea-level atmospheric pressure records as a see-saw of high pressure in the South Pacific Ocean and low pressure in the Indian Ocean alternating with the opposite conditions in the other phase of the cycle. It has a characteristic cycle length of a couple of years and may occur at 2- to 10-year intervals. It is the most obvious instance of interannual climate variability.

Associated with the Southern Oscillation are sea-surface temperature anomalies in the Pacific, Indian, and Atlantic oceans. Changes in the equatorial current system and the heat content of the Pacific Ocean are particularly marked. The largest oceanic anomaly is El Niño, a sea-surface warming off South America. El Niño brings destruction to the fisheries off Peru and Ecuador. Plankton, fish, and birds, depending in a chain for nutrients provided by the upwelling of cold seawater off the coast, die. This has economic effects on the global markets for fish, poultry, and fertilizer. El Niño also brings heavy coastal rains that cause flooding and damage crops along the South American coast.

The Southern Oscillation has climatic significance because it is a strong signal and because of its time scale [*Climate Research Committee*, 1983]. Though the Southern Oscillation does not occur regularly, an occurrence has correlated manifestations that normally persist for nearly 2 years from first to last appearance. This duration offers the potential to develop a predictive capability of perhaps a few months. The stages of the oscillation are tied to the annual cycle. That is, the component phenomena of the Southern Oscillation normally occur at specific seasons of the year.

From the viewpoint of the United States, the correlations of the Southern Oscillation with North American climate anomalies present an intriguing challenge. Can the Southern Oscillation be used to predict wintertime climate anomalies over the United States a season in advance?

Correlations between the Southern Oscillation and North American climate anomalies were first described in the 1930's by Sir Gilbert Walker. Since that time there has been growing evidence of the reality of these correlations. Wintertime temperature anomalies are correlated with earlier atmospheric pressure anomalies over the South Pacific and with sea-surface temperature anomalies in the equatorial Pacific Ocean.

During the winter of 1982–1983, the strongest El Niño event ever observed took place. It was not forecast, it was not generally recognized as an El Niño occurrence until it was well developed, and its subsequent evolution and duration were not anticipated. Considerable research has been stimulated by this event which underlined the incomplete state of our understanding.

The link between the tropical Pacific Ocean and the atmosphere has attracted considerable scientific attention. The Atlantic and Indian oceans also provide interesting but different examples of large-scale interactions between the ocean and the global atmosphere. Atlantic sea-surface temperature anomalies correlate with droughts in Brazil. Those in the Indian Ocean correlate with variations in the Indian monsoon. As in the Pacific, tropical sea-surface temperature anomalies influence and in turn are influenced by the atmosphere.

The Indian Ocean region appears to play an important role in the Southern Oscillation. In addition, there is a large seasonal change in the Indian Ocean in response to the monsoon. The Somali Current, for instance, reverses its direction seasonally. The Indian Ocean thus provides a unique location for studying some kinds of large-scale interaction between the ocean and the atmosphere. Indeed, the early evolution of Southern Oscillation appears to occur in the atmospheric circulation over the southern Indian Ocean.

An experiment to study the Southern Oscillation and other interannual climate variation has been proposed. It is called the Interannual Variability of the Tropical Ocean and the Global Atmosphere Experiment (TOGA).

TOGA is an exciting opportunity. The Southern Oscillation is a strong climate signal. The economic benefits that could be derived from predicting the associated climate anomalies could be great. A number of excellent scientists are enthusiastically working on the problem. Progress is being made in data analysis, field experiments, and theoretical work. On the negative side, there is yet no comprehensive theoretical framework for TOGA. The first fragments of a theory exist, and some linking physical mechanisms have been hypothesized. However, there is not yet a strong enough base of theory to design a full TOGA experiment with assurance.

To summarize, the Southern Oscillation presents a strong natural signal that promises a predictive capability for climate variations in temperate latitudes. The opportunity to study this phenomenon should not be missed, and the United States should support a major TOGA experiment in the Pacific. At the same time, complementary TOGA research activities should be supported in the Atlantic and Indian oceans, though other nations may play the principal role there.

World Ocean Circulation Experiment

We must understand the global oceanic circulation to understand the oceanic role in maintaining the climate state and in influencing climate variability. Without this knowledge we are unlikely to be able to predict future climate variations.

A large-scale oceanographic experiment to examine global ocean circulation and ocean climate processes is proposed. The World Ocean Circulation Experiment (WOCE) will be directed at describing the circulation of the ocean, defining the linking physical processes in the ocean-atmosphere climate system, and understanding the sensitivity of that system to forcing by changes in the atmosphere.

Recent oceanographic studies have exposed a number of processes that could be important to the ocean's role in climate variability: mesoscale eddies, tropical waves, isopycnal mixing, the seasonal variation of the mixed layer, and mixing in the interior of the ocean. Computer models of the large-scale ocean circulation underline the importance of some of these processes. Thus, to observe and understand the climate of the ocean, we need to describe the processes relevant to climate in the ocean in enough detail to model them.

A major obstacle to obtaining observations of the ocean is the difficulty of obtaining measurements over long time scales and over great distances. Recent technical developments and new means of making measurements have made it feasible to consider carrying out a global experiment to understand the role of ocean circulation in climate. Orbiting satellites give promise of regular global measurements of sea-surface temperature, surface currents, and the wind stress on the sea-surface. If these observations are combined with subsurface remote sensing, it may be possible to develop a description of the ocean that, for the first time, would begin to be as complete as our description of the atmosphere.

A stated objective of WOCE is "to describe and understand quantitatively the general circulation of the ocean, in order to assess within the WCRP the sensitivity of the climate system to changes in external forcing, whether natural or anthropogenic, on time scales of decades to centuries" [*Committee on Climatic Changes in the Ocean*, 1983a]. The proposal for WOCE has three types of scientific objectives:

1. To describe the general circulation of the ocean.
2. To understand the rates and processes of water-mass transformation.
3. To describe the spectrum of seasonal and broad-band ocean variability

To provide the basis of knowledge to understand the state of the ocean, we must describe the mean circulation of the ocean over several years as well as the space-time variability on time scales of months to years. This might in part be done as a global experiment lasting 5–10 years. In addition, special studies could focus on processes that would elude an experiment of this duration.

A common thread in many WOCE component studies is an earth-orbiting satellite that measures sea-surface elevation by altimetry and surface wind stress by scatterometry. Sea-surface elevation can define the field of surface geostrophic currents. With complementary measurements, such as of the density field in the interior of the ocean, the circulation of the ocean might be determined. Drifting and fixed buoys could provide complementary measurements. An intriguing possibility is to combine satellite observations of altimetry and wind stress with ocean acoustic tomography [*Munk and Wunsch*, 1982] to provide an ocean-observing system. This might be a major step in providing the kind of synoptic information in the ocean that has long been taken for granted in the atmosphere.

Proposals within NASA for an altimetric satellite have not been accepted so far by the administrator. This may in part be due to lack of a perceived consensus need for such a satellite. The European Space Agency is planning a Seasat-like satellite that will measure altimetry, to be launched in 1987. Japan may launch a satellite with an altimeter in 1990. The precision of these satellites may not be as great as that proposed for a U.S. altimetric satellite (TOPEX), but they could allow WOCE to proceed.

Satellite altimetry and scatterometry are essential for WOCE, for ocean climate monitoring, possibly for heat flux studies, and possibly for TOGA. There is thus a vital need for an earth-orbiting satellite for future ocean and climate research. To proceed with large-scale ocean experiments in the next decade, there will soon need to be commitments for satellites to support them.

Heat Transport Studies

Transport and storage of heat by the ocean is central to all theories of the role of the ocean in global climate and thus is central to predicting climate variations. As the study began, there were a number of proposals for major heat flux experiments. These experiments are now likely to take place as components of WOCE and TOGA.

The ocean dominates the energy storage of the combined ocean-atmosphere system. Heat can be stored in the ocean for periods that are long in comparison with atmospheric residence times. The ocean can transport this heat and give it up to the atmosphere far from the place where it was received. *Oort and Vonder Haar* [1976] estimate that the ocean has a heat transport poleward from the tropics to mid-latitudes as large as mid-latitude atmospheric transport.

Heat flux is central to all ocean climate models. For model testing we need to be able to determine the poleward transport of heat by the oceans and its variation with time. Techniques for estimating ocean heat transport are subject to uncertainty. To deal confidently with the question of ocean heat transport, there must be means for measuring it to provide assurance in the estimates.

Two ocean heat flux experiments have been proposed to explore the storage, transport, and transfer of heat by the ocean. The Cage experiment would examine the long-term mean heat flux, the annual cycle, and the interannual variability over the North Atlantic. The Pacific Transport of Heat and Salt (PATHS) program would investigate the short-term climate variability in the distributions of heat and salt in both the subarctic and subtropical gyres of the North Pacific, on time scales of months to years, for a period of approximately 10 years. It would also estimate transports and air-sea fluxes from time-dependent measurements of heat and salt storage.

Many of our ideas about North Atlantic heat flux are stimulated by the direct estimate of *Hall and Bryden* [1982] of the poleward heat flux across 25°N latitude in the Atlantic. A corresponding estimate for the Pacific does not exist. In fact, the order of magnitude of the Pacific poleward heat transport is not known. We are being held back in developing our ideas about the North Pacific because of the lack of a trans Pacific Ocean poleward heat flux measurement.

Ocean Climate Monitoring

Monitoring, the collection of regular observations of the ocean and atmosphere over large regions for long periods of time, is a necessary element for progress in understanding climate variability. Yet, there is so far no commitment to establishing large-scale ocean climate monitoring programs, particularly in the ocean.

The long time scale of ocean climate anomalies may be an important factor for forecasting, but the length of time needed to describe and understand them presents a problem in experimental design. Events like the Southern Oscillation occur sporadically (typically at 2- to 7-year intervals) and have a cycle length of about 2 years. Such large-scale ocean-atmosphere interactions must be described over several events because of their complex nature. A description of a single event would not be sufficient to understand the phenomenon because each occurrence is different. An ensemble of descriptions is needed to separate out overlapping events and to define the phenomenon. Thus the time needed to describe and understand the Southern Oscillation is long.

It is thus important to have some means for ocean climate monitoring that can give regular, reliable, and repeated oceanic and atmospheric observations over the course of many years.

The next steps need not be elaborate. Many proposals for doing this have been made. The *Ocean Science Committee* [1974], in a series of workshops led by Henry Stommel, recommended the establishment of "phantom weather ships." In this program, commercial ships would collect measurements as they passed certain designated points in the ocean. The resultant time series would provide regular samples at fixed locations much as the ocean weather stations did but without the

Oceanography (cont. on p. 468)

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Cover: The Olympic Yachting Venue Chart, produced by NOAA's National Ocean Service, shows the four areas (venues) in San Pedro Bay and Channel where seven classes of sailboats will compete, the waters that will be off limits during the July 30 to August 10 competition, the racing schedule, and other general information. While it resembles the nautical charts for which the National Ocean Service is globally renowned, this one cannot be used for navigation. Information critical to safe navigation in the area, including restricted areas, traffic separation zones, and LORAN C lines do not appear, so that race areas can be more clearly depicted. For navigation in the area, NOS Nautical Charts 18746, 18747, 18749, 18751, or 18752, available from chart dealers in the area, should be used. The free, full-color Olympic Yachting Venue Chart may be obtained without charge from the U.S. Coast Guard's 11th District in Long Beach, Calif. (See article, "New Directions for the National Ocean Service," in this issue's *The Oceanography Report*.)

Oceanography (cont. from p. 467)

great expense of maintenance. There has been no move toward implementation. The obstacle seems more to be a lack of coordination than a lack of money.

Another source of climate information could be gained by extending the global network of sea-level observation. This would be particularly effective if extended to isolated islands. Proposals for sea-level observations go back many years. Since it is relatively inexpensive (e.g., compared with satellites), what is holding us back? International coordination is an issue. In addition, the collection of simple sea-level measurements over many years is not perceived as an attractive activity: The payoff is distant, the technology is not glamorous, and the program demands a long-term commitment. Nevertheless, to advance our knowledge of the ocean's role in the global climate system, sea-level measurements are important and effective.

To develop an effective ocean climate monitoring methodology, estimates of the space and time spectrum of oceanic variability for many regions of the ocean are first needed. Further, trial time series can explore the possible benefits of and practical means for monitoring various regions of the ocean. We call such short-term observational programs "exploratory time series."

Exploratory time series should be designed to resolve the spectrum of variability, to examine the feasibility of observational techniques, and to assess the benefits that might be obtained from future monitoring. They should be geographically dispersed, incorporated into large-scale oceanographic experiments, and used as a preliminary to ocean climate monitoring. Research scientists will normally design and establish the exploratory time series and analyze and review the results. Ocean climate monitoring, on the other hand, will normally be an operational activity, as monitoring now is in the atmosphere.

Although exploratory time series are a useful preliminary step, ocean climate research programs will need a reliable source of routine global data. Thus, there ultimately must be a commitment to ocean climate monitoring.

Other Ocean Climate Research Issues

The large, internationally sanctioned ocean climate programs receive most of the attention, here as elsewhere. Yet a number of competent ocean scientists concerned with the climate variability problem are not convinced that they should work within the big programs. Oceanography has a tradition of independence. Some oceanographers interested in climate are reluctant to relinquish that independence in order to work within the large programs.

Ocean climate research is concerned, by definition, with global scientific questions. Can they be effectively addressed by independent studies? The easy course of action, and one that is not hard to defend, is to insist that oceanographers (and perhaps meteorologists) work together to study climate. Nevertheless, many ocean scientists who lack the taste for big programs have the potential to make progress in understanding climate. These people should not be excluded because they prefer not to work in big science. Whatever decisions are made about the big programs, NSF should continue to be flexible enough to support good ocean climate research ideas even when they are outside the "approved" framework.

Some oceanographers contend that global ocean climate planning is overblown and perhaps even unrealistic, that it does not take account of the difficulties in obtaining reliable data in the field, and that a better description of the ocean's structure and circulation is needed before moving on to understanding the ocean's role in climate. They argue for simpler field programs.

There is concern, too, that a global program should not begin before we are scientifically and technically ready to carry it off well. If we were to try prematurely and fail, it is likely that the funds to do it right would be a long time in coming.

A number of ideas for ocean climate research outside of the official programs have been presented that could improve our knowledge of climate variability. Some of these ideas may end up as components of the big programs (like WOCE) as program planning evolves. Among the ideas are the following:

1. Make a few long, deep hydrographic sections intended to provide a base of information about interior low-frequency ocean movements and dynamics.
2. Maintain and perhaps extend island tide stations in the western Pacific Ocean.
3. Maintain the Pacific XBT monitoring program, TRANSPAC.
4. Carry out some small experiments to understand the physical processes that are important components in climate, such as air-sea fluxes of heat, water, and momentum.

Some ocean studies that may be important are less fashionable. Few oceanographers are studying the polar regions. Is the role of the ice-covered regions in climate variability receiving enough attention? This question has been reviewed, but there has been little followup.

National Coordination

An ocean research program to understand climate change is too large to be supported by a single U.S. government agency. Several agencies will have important roles to play. However, a review of climate documents reveals that agencies often do not have a clear image of their role. One sometimes gets the impression that no clear criteria have guided an agency's choice of work.

The National Climate Program Office (NCPO), housed in NOAA, is responsible for administering the National Climate Program and coordinating among the agencies in the program. NCPO looks to NSF, as lead agency, for development of plans, budget requirement, agency responsibilities, and progress reports related to the Ocean Heat Transport and Storage Principal Thrust.

The NSF, as lead agency for Ocean Heat Transport and Storage, has the de facto responsibility for oversight of the national ocean climate research program. NSF has been doing this through informal meetings with representatives of other agencies and by making extensive use of the National Research Council (the Board on Ocean Science and Policy and the Climate Research Committee, in particular). If problems arise that involve the setting of priorities among the agencies, it may be necessary to set up a more formal steering mechanism.

All the lead agencies in the National Climate Program have had difficulty in coordinating their components. There is thus no good model for NSF to follow. NSF is the largest supporter of ocean climate research and has credibility with the other agencies in its lead role.

NSF research programs related to climate have typically involved collaborative research projects from a number of institutions. These programs may have a duration of from 3 to 5 years. Such a mode of operation tends to yield results that respond to specific scientific questions but is not well suited to programs that require a continuing year-after-year commitment. Long-term programs need to be part of a climate research program, and, hence, there is a need for other agencies that can support them to play a role complementary to that of NSF.

The National Oceanographic and Atmospheric Administration (NOAA) has been supporting a substantial ocean climate research program. NOAA programs include the Equatorial Pacific Ocean Climate Studies (EPOCS), the Subtropical Atlantic Climate Study (STACS), and oceanographic components of the Global Atmospheric Research Program (GARP). NOAA also has the lead responsibility for the U.S. TOGA program.

In addition to carrying out ocean climate research, NOAA has other responsibilities that are important to the climate program. NOAA is the lead agency for the principal thrust of the National Climate Program entitled "Generation and Dissemination of Climate Information." NOAA's Environmental Data and Information Service runs the National Climatic Center that manages oceanographic data. As the climate program progresses, the management of data and information will be a factor in its success. Thus, these elements of NOAA need to be involved in the planning for large ocean climate experiments. NOAA's National Ocean Service (NOS) has responsibility for ocean monitoring. To date, NOS has exercised that responsibility chiefly in conventional mapping and charting services. They have missed opportunities to support monitoring useful to ocean climate, such as the Pacific tide gauge network. A global study of the ocean's role in climate demands reliable ocean observations, analogous to those taken for granted in the atmosphere. NOS ought to be working toward developing an ocean service on a par with the atmospheric service provided by the National Weather Service. Although NOS has not so far given a high priority to developing this capability, perhaps the creation of the National Ocean Service, from what had been the National Ocean Survey, will lead NOAA, through NOS, to accept responsibility for the needed ocean climate monitoring.

The National Aeronautics and Space Administration (NASA) has the goal of developing spaceborne techniques for observing the oceans and thereby understanding oceanic behavior. NASA's spaceborne oceanic observations are intended to study oceanic circulation, heat content, and heat flux. Such work involves the interaction of the ocean with the atmosphere and the effect of the ocean on climate. NASA has focused on scientific questions addressable by specific earth-orbiting satellite oceanographic sensors. They have commissioned a series of studies that, though not specifically directed to climate research, provide a valuable summary of satellite oceanographic capabilities and needs.

WOCE will depend critically on remote sensing by satellite of sea-surface elevation, surface wind stress, and meteorological variables. Thus, something like the TOPEX satellite, with altimeter and scatterometer for global sensing of surface ocean currents and surface wind stress, is essential for WOCE. To date, NASA has not made a decision on this program, and the uncertainty is a major deterrent to the development of U.S. plans for WOCE.

The Office of Naval Research (ONR) does not now explicitly support ocean climate research. ONR does, however, support a number of process studies, particularly at the air-sea interface and in the surface mixed layer, that are relevant to climate. For example, work supported by ONR may be important in resolving the question of the sea-surface water-vapor flux. Our current understanding of ocean/atmosphere climate interaction owes a great deal to the results of the NORPAX program, which was supported for many years by ONR. ONR is also supporting the development of techniques in remote sensing that have direct application to ocean climate research experiments. Furthermore, naval operational activities need environmental information of the type that is important to climate research.

An important ingredient in the implementation of large-scale ocean climate research programs is a consensus opinion from U.S. oceanographers that the experiments can be done and should be done. A commitment by capable scientists to participate and to see that the experiments are successful is also needed. Without the consensus and the commitment, the federal agencies will find it difficult to develop the new funding needed for supporting these experiments.

One ingredient in developing a consensus is to allay the fears of many oceanographers that all new ocean research funds will go to the large programs, like WOCE. This concern needs to be addressed. The federal agencies, and particularly NSF, must be involved. The climate program advocates in the scientific community cannot assure their colleagues in other ocean research disciplines that a proper balance will be found. Those controlling the money must give this assurance. Here is an opportunity for program managers in NSF and other agencies to seek the opinions of oceanographers of all stripes, not just those with climate research interests. What should be the appropriate balance of support for these programs? What is the view of biological and geological oceanographers (for example) about the need for strong support of ocean climate research? Answers to such questions might be sought through National Research Council committees.

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News & Announcements

Seismometer Washes Ashore

An ocean bottom seismometer (OBS) recently washed ashore at Wake Island and was shipped to the Hawaii Institute of Geophysics. It appears to be instrument number 4 of the Texas Instrument Mark III series, built in 1964 for the Air Force Technical Applications Center. Some leakage into the sphere is indicated by moderate corrosion of the internal components. About half of the tape was pulled across the head.

Several such instruments were used and lost in experiments (recording of earthquakes and underground explosions) off the Kuril and Aleutian islands in the late 1960's and early 1970's. Some instruments (serial numbers unknown) in the Mark II series may have been lost as early as 1964. Of the 18 Mark III instruments, 11 had been lost as of July 1968; we are unaware of their use (or the use of Mark IV's or V's) in recent years.

This OBS may have been in the ocean for an unprecedented number of years, and valuable data may still be present on the tape. We ask those who may be interested or who could provide details on the last experiment in which this instrument was used to please call or write Charles McCreery or Dan Walker, Hawaii Institute of Geophysics, 2525 Correa Road, Honolulu, HI 96822 (telephone: 808-948-8767).

This news item was submitted by Daniel Walker of the Hawaii Institute of Geophysics.

Emerging Ocean Issues

Seven topics have been identified by the topics committee of the Year of the Ocean as focal points of discussions as part of the Year of the Ocean celebration. The Year of the Ocean (*Eos*, June 19, 1984, p. 402, and April 24, 1984, p. 326) is a year-long commemoration and celebration, begun on July 1, of the oceans. The commemoration has been endorsed by Congress and by President Ronald Reagan.

The topics committee is composed of nearly 20 representatives from government, industry, and academia. Thomas Maginnis, director of the National Oceanic and Atmospheric Administration's office of policy and planning, is the chairman of the topics committee.

Summaries of the discussion topics and the requisite questions, as described by the Year of the Ocean, are listed below.

- Effects of Oceans on World Climate. How does the ocean affect our climate and weather? How close are we to predicting climatic extremes? What are the consequences of such predictions?
- Marine Transportation. The U.S. Merchant Marine ranked first in deadweight tonnage in 1950, but by 1980, it had dropped to eighth. The U.S. relies on marine transportation for 99% of its export and import trade. What is happening to our Merchant Marine and why? How many ports can the U.S. economy continue to support? Can technology lower ship building and operating costs enough to make these industries more competitive? Will the United States have a reliable merchant marine force for national emergencies?
- The Oceans as a Source of Food. Although fish and other living marine resources provide important sources of protein throughout the world, many fish stocks have been overfished, and marine and estuarine habitats have been polluted. Domestic and international competing fishing interests require that fish stocks be managed so that populations remain stable or increase. Is the current system of allocating fish resources working adequately? What steps are being taken to determine habitat needs of important marine species? What is being done to develop markets for currently underutilized species? What is the future of aquaculture in the United States?
- The Ocean as a Source of Minerals. Do we have adequate surveys of marine mineral resources? What do we currently know about deposits there? What are the technological capabilities and limitations of developing mineral resources in extreme environments? Is technology for controlling accidents adequate? What are the ramifications of the United States not signing the Law of the Sea Treaty on development of marine mineral resources in international waters?
- Marine Recreation. Are the fish caught by recreational fishermen safe to eat? Are saltwater fishing licenses for sportsmen a way of funding research and habitat enhancement projects for recreationally important species? Are navigational aids maintained and charts updated to insure safe boating? In how many places is the water unsafe for swimming? What are the proper practices for controlling coastal erosion in specific locations such as beaches and channels?
- Ocean Pollution, Dumping, and Hazardous Waste Management. Can the U.S. government find a balance between our need to dispose of wastes and the necessity for a healthy environment? Have we fully realized the reverberations of such dumping on the delicate balance of marine ecosystems (i.e., the food chain)? Are our current dumping patterns stretching the assimilative capacities of the oceanic waters? Can we assess the fate and effects of past dumping of hazardous wastes in the ocean?
- Future Ocean Exploration and Technology. Topics for discussion include studying the ocean from space and alternate energy sources and ocean thermal energy conversion (OTEC).—*BTR*

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POSITIONS AVAILABLE

Geochemist. The University of California, Davis, Department of Geology, has an opening for a one year temporary faculty position for Fall 1984. Specific fields are open; however specialization in isotope and economic geochemistry are desirable. The Department has strong programs in paleobiology, paleoceanography, petrology, geophysics, and crust and mantle evolution. A Ph.D. is required. Responsibilities include graduate and undergraduate teaching and research in geochemistry.

Applicants should submit vita, statement of research and teaching interests, and the names of three referees as soon as possible, as the position is for the Fall, 1984 quarter.

We anticipate that this position will be opened on a permanent, tenure track basis during the next academic year. A successful candidate for this temporary position can apply for the tenure track position. Inquiries and applications should be sent to Chair, Search Committee, Department of Geology, University of California, Davis, Davis, California 95616.

The University of California is an equal opportunity/affirmative action employer.

Geologists-Geophysicists/Institute for Geophysics, The University of Texas at Austin. The Institute for Geophysics at the University of Texas at Austin has openings for research staff, particularly in the areas of theoretical seismology and sea-going marine geology/geophysics. The Institute is located in Austin and operates closely with the Department of Geological Sciences of the University. It is a vigorous and growing group with interests in both land and marine geology/geophysics. Research facilities include a 169-foot ship equipped with multichannel and high resolution seismic reflection and OBS seismic refraction capabilities. A VAX 11/780 computer with DISCO software is available for data processing.

Applicants should hold a Ph.D. in geology, geophysics or other appropriate field and have demonstrated creativity in research. Senior and mid-career researchers as well as recent Ph.D.'s are encouraged to apply. Applications should be received by September 15, 1984. The salary is dependent upon qualifications. Please forward applications, curriculum vitae, names of at least three references, and other supporting materials to: Dr. A.E. Maxwell, Director, Institute for Geophysics, The University of Texas at Austin, P.O. Box 7456, Austin, TX 78712.

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Stanford University/Plasma Physics, EM Waves, Space Physics. We are seeking a senior person who has demonstrated scientific, managerial, and leadership qualifications in one or more of the following disciplines: Space Plasma Physics, electromagnetic waves, and solar-terrestrial physics. We expect the successful candidate to have established an outstanding reputation documentable through professional writings or other evidence of personal technical creativity, letters of reference from recognized research leaders in the disciplines mentioned above, and/or awards and other recognition from appropriate professional societies.

It is expected that this individual will develop a research program in one of the disciplines given above working in coordination with ongoing programs within the STAR Laboratory and, possibly, with other activities within the Stanford Center for Space Science and Astrophysics. It is expected that this individual will have a strong background in experimental techniques, either in the laboratory or in the field, including the environment of space; experimental activities in either laboratory or space plasma physics would be regarded as good qualifications. However, close association with theoretical developments in plasma physics and/or electromagnetic theory will clearly be desired. It is also expected that the individual will have a demonstrated capability for securing federal or other research grant support, or be deemed by the selection committee of being capable of securing such funds.

It is anticipated that the person chosen will devote the major part of his or her time to research activities. However, there is an opportunity for participation in academic responsibilities of Electrical Engineering Department, including, when time permits, teaching graduate and undergraduate classes, serving on various committees of the department, School of Engineering, and the University. It is expected that the person chosen will participate actively in the training of graduate students.

The Chairman of the selection committee for this position is Professor Robert A. Helliwell, Professor of Electrical Engineering, Space, Telecommunications, and Radioscience Laboratory, Stanford University, Stanford, CA 94305. Other members of the selection committee include Professor P.M. Banks, Professor R.N. Bracewell, Professor L.R.O. Storey, and Professor L. Tyler.

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University of Texas at Austin. The Department of Geological Sciences invites applications for a person to teach depositional systems and petroleum geology at the undergraduate and graduate levels and to conduct a vigorous research program, including the supervision of graduate students, in the area of the person's interest. The person must be willing to teach the above subjects to non-majors on occasion. The position requires the Ph.D. and is open to both tenure-seeking junior persons and senior-level persons. Availability by January 1985 is desirable. Applicants should submit a detailed resume, names and addresses of five references, and a statement of teaching and research interests by November 1, 1984 to Dr. Earle F. McBride, Department of Geological Sciences, University of Texas, Austin, Texas 78712. New Ph.D.-holders should also submit a copy of their dissertation abstract.

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Hydrogeologist/Texas A&M University. The Department of Geology and Center for Engineering Geosciences have a tenure track opening, preferably assistant professor level, for which the first search will be for a creative individual working in applied geological hydrology.

The successful applicant will be expected to develop teaching and research recognition at a national level. The position is available beginning September 1, 1984 and will be held open until filled. Applicants should submit a vita including names of references to M.C. Gilbert, Department of Geology, Texas A&M University, College Station, TX 77843.

Texas A&M University is an affirmative action/equal opportunity employer.

Faculty Positions/Florida State University. The Department of Meteorology, Florida State University, expects to appoint two faculty members in August 1985 at the rank of assistant professor or associate professor. These are tenure-earning positions requiring the Ph.D. degree. Candidates with training and experience in synoptic meteorology or climatology are preferred; but all qualified candidates are encouraged to apply. The appointee will be expected to teach; to develop an active research program and to participate in the governance of the department. Applicants should send comprehensive resumes, including a list of publications and the names and addresses of three professional references to: Chairman, Department of Meteorology, Florida State University, Tallahassee, FL 32306. The last date for receipt of applications is December 31, 1984.

Florida State University is an equal opportunity/affirmative action employer and invites applications from all qualified candidates.

Satellite Geodesist. The scientific staff position available 1 October 1984 at the Massachusetts Institute of Technology, Department of Earth, Atmospheric, and Planetary Sciences, in a federally sponsored long-term program of research in geodesy via radio interferometry with Global Positioning System (GPS) satellites. Candidates must have Ph.D. in geodesy, and ability and experience in radio interferometry with satellites, as demonstrated by substantial publications and reference reports. Expertise in FORTRAN scientific programming, in statistics, in the theory of satellite geodesy, and in parameter estimation techniques applicable to large, multi-parameter geodetic problems is essential. Experience in performing field work and in data processing on large IBM mainframe and/or small PDP-11 computer systems would be helpful, as would knowledge of the GPS, geodetic reference systems, and network adjustments. Strong skills in oral and written presentation of research results are required.

Please send vita, including list of publications, salary requirements, and references, plus reprints of major publications to:
Professor Charles C. Counselman, III
c/o L.M. Birchette
Personnel Office, E19-238
M.I.T.
Cambridge, MA 02139

MIT is an affirmative action/equal opportunity employer.

Postdoctoral Position/University of Arizona. A postdoctoral position has been opened at the Lunar and Planetary Laboratory, University of Arizona, Tucson, Arizona, in July 1984. The research is in the general area of space and planetary physics with much of the work related to Voyager EUV observations at the outer planet encounters. The program includes work in plasma physics concerned mostly with the fundamental nature of the to plasma toruis, upper atmospheric and auroral processes on Jupiter, Saturn, Titan, Uranus and Neptune, exosphere-magnetosphere modelling at Saturn, and some specialized aspects of the interstellar-interplanetary medium. The applicant should have a background in atomic and molecular physics with an interest in planetary atmospheres. Applications should contain vita, statement of interests, and names of three references, and should be submitted by August 30, 1984. Further information can be obtained by contacting D. E. Shemansky, Lunar and Planetary Laboratory, 3025 E. Ajo Way, Tucson, Arizona 85713; 602-621-4304.

The University of Arizona is an equal opportunity/affirmative action employer.

University of Texas at Austin. The Department of Geological Sciences seeks to fill tenure track positions effective fall 1985 in one or more of the following disciplines: 1) micropaleontology-Tertiary biostratigraphy, 2) structure-tectonics, 3) hydrogeology, and 4) mineralogy-kinetics. Each person is expected to teach both undergraduate and graduate courses and to conduct a vigorous research program, including the supervision of graduate students, in the area of his or her speciality. The positions require the Ph.D. degree. Applicants should submit a detailed resume, names and addresses of five references, a statement of teaching and research interests, and a copy of their dissertation abstract by December 1, 1984 to: Dr. William L. Fisher, Department of Geological Sciences, the University of Texas at Austin, Austin, Texas 78713-7909.

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Project Associate/Specialist: Electron Micro-Probe Lab, University of Wisconsin-Madison. Strong analytical background in quantitative EMP analysis and familiarity with computers is required. The Lab has a 9-spectrometer ARL SEMQ and a JEOLCO 50-A SEM. Duties will include instrument maintenance, instruction of students, development of procedures and analysis. Research will be encouraged. A MS or PhD is required in Earth Science, Chemistry, Physics or Engineering. Minimum salary will be $18,000/12 months with an MS. Send letter of application, transcripts, resume, and names and addresses of three references by September 15 to Dr. John W. Valley, Department of Geology & Geophysics, Weeks Hall, University of Wisconsin, Madison, WI 53706.

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Faculty Positions in Geophysical Sciences/The University of Chicago. The Department of the Geophysical Sciences invites applications for positions at all levels across the entire range of earth and planetary sciences, including meteorology and oceanography. Particular attention will be given to applications in interdisciplinary areas with prospects of major advances in observation, theory and application. Please send resume and reprints to Joseph V. Smith, Chairman, Appointments Committee, 5734 South Ellis Avenue, Chicago, Illinois 60637, USA. Applications will be considered rapidly throughout the year.

The University of Chicago is an equal opportunity/affirmative action employer.

Princeton University. The Department of Geological and Geophysical Sciences invites applications for a tenure track appointment beginning September 1, 1985, at the Assistant Professor level in the area of Isotope Geology with specialization in $^{40}Ar/^{39}Ar$ mass spectrometry.

Candidates must be thoroughly grounded in the fundamentals of isotope studies (stable and radiogenic) and their application in earth science, and have demonstrated an ability for research in this or related fields. The appointee will be expected to supervise our newly assembled continuous-laser-heating Argon age laboratory, and to participate in collaborative research programs using this facility. Teaching duties are to complement and expand the existing programs.

Applicants should send resume and names of three referees to Robert A. Phinney, Chairman, Department of Geological and Geophysical Sciences, Princeton University, Princeton, N.J. 08544.

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SERVICES, SUPPLIES, COURSES, AND ANNOUNCEMENTS

Consultant. Specialist in resource exploration and development (mineral, petroleum, and groundwater–mining and petroleum engineering). Johns Hopkins PhD with extensive practical experience in the Middle East and elsewhere. Multilingual (fluent in Persian and Turkish). Reply to Box 024, American Geophysical Union, 2000 Florida Avenue, N.W., Washington, D.C. 20009.

NATO Advanced Study Institute/Large Scale Transport Processes in Oceans and Atmosphere. Les Houches, French Alps, February 11–22, 1985.

A primary objective of the course is to develop understanding of the large scale atmospheric dynamics, ocean dynamics and the interactions between ocean and atmosphere. The principal lecturers (Blackman, Gill, Hoskins, Rhines, Welander) will cover the above topics, starting at a relatively simple level and developing them to advanced research level. In addition, a number of more specialized lectures will be given by supporting lecturers.

The Institute is intended for graduate students or young postdoctoral researchers. Limited funding is available. Students should write to Dr. J. Willebrand, Institute für Meereskunde, Düsternbrooker Weg 20, D-2300 Kiel 1, W. Germany, for further information, as soon as possible.

Request for Preproposals. The U.S. Environmental Protection Agency's Corvallis Environmental Research Laboratory is seeking PREPROPOSALS for research on the effects of acidic deposition on the chemistry of surface waters. The purpose of the research will be to improve our understanding of the mechanisms of surface water acidification with the ultimate goal of predicting such effects of acidic deposition on regional and national scales. Specific areas of research to be addressed are: (1) retention of sulfate within soils; (2) flux of base cations from soils; (3) hydrologic response of watersheds; and (4) development/application of watershed-scale models for prediction of future effects. Written requests for information on preproposal submission are to be received not later than September 14, 1984, and are to be forwarded to: Dr. Raymond G. Wilhous, Chief, Air Pollution Effects Branch, U.S. Environmental Protection Agency, 200 S.W. 35th Street, Corvallis, Oregon 97333. Please specify research area of interest.

AGU

AGU Membership Applications

Applications for membership have been received from the following individuals. The letter after the name denotes the proposed primary section affiliation.

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Meetings

Announcements

The last Geophysical Year calendar ran July 17, 1984, in *Eos*.

Future AGU Meetings

Fall Meetings

- Dec. 3–7, 1984, San Francisco, California. Abstracts due September 12, 1984; call for papers appeared in July 3, 1984 *Eos*.
- Dec. 9–13, 1985, San Francisco, California. Abstracts due mid September 1985.
- Dec. 8–12, 1986, San Francisco, California.

Spring Meetings

- May 27–31, 1985, Baltimore, Maryland. Abstracts due early March 1985.
- May 19–23, 1986, Baltimore, Maryland.

Regional Meetings

- Pacific Northwest Regional Meeting, September 7–8, 1984, Corvallis, Oregon. Abstracts due August 1, 1984; call for papers appeared in June 12, 1984 *Eos*.
- Front Range Branch Hydrology Days, April 16–18, 1985, Fort Collins, Colorado. Abstracts due December 31, 1984 for professional hydrologists, February 15, 1985 for students; call for papers appeared in July 24, 1984 *Eos*.

Chapman Conferences

- Vertical Crustal Motion: Measurement and Modeling, October 22–26, 1984, Harpers Ferry, West Virginia.
- Solar Wind-Magnetosphere Coupling, February 12–15, 1985, Pasadena, California. Abstracts due November 1, 1984; call for papers appeared in July 10, 1984 *Eos*.
- Ion Acceleration in the Ionosphere and Magnetosphere, June 3–7, 1985, Boston, Massachusetts.
- Magnetotail Physics, October 28–31, 1985, Laurel, Maryland.

Water Policy and Research

September 11–12, 1984 National Water Alliance Symposium: Water Policy Trends and the Role of Supporting Research, Washington, D.C. Sponsor: National Water Alliance. (National Water Alliance, 50 E St., S.E., Washington, DC 20003, tel.: 202-646-0917.)

The purpose of the symposium is to explore the implications of research and information for national water policy, and to culminate the public discussion of the establishment of water-related research and information institutes. Among the topics to be discussed are environmental issues and planning; the role of water-related research and information dissemination; water policy trends and research support for rural health and development and for urban health and development; and the structure of research centers and information clearinghouses.

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Aeronomy

0418 Aeronomy (Mesospheric Scattering)
COMPARISON OF MESOSPHERIC VHF RADAR ECHOES AND ROCKET-PROBE ELECTRON-CONCENTRATION MEASUREMENTS
B. Røyrvik and L. G. Smith (Aeronomy Laboratory, University of Illinois at Urbana-Champaign, 1406 West Green Street, Urbana, Illinois, 61801)

Refractive index irregularities in the equatorial mesosphere have been investigated using both the Jicamarca VHF radar and a rocket-borne Langmuir probe launched from Punta Lobos, Peru. On February 27, 1983, a single layer of turbulence was observed in the upper mesosphere by both experiments. There is very good agreement between the observed radar echo power and the radar scattering cross section calculated from the rocket data when these are interpreted in the context of isotropic turbulence. The inner and outer scales of turbulence have been calculated from both the radar and the rocket data and good agreement is found. The radar data show indications of large-scale vortices in the layer of irregularities. Rocket data show that the inner scale of turbulence in the upper mesosphere is a few tens of meters, and that the Jicamarca radar Bragg wavelength (3 m) is well within the viscous subrange of turbulence in this altitude range. The spectral index in the inertial subrange is close to −5/3, changing to about −7 at higher wave numbers. Energy dissipation rate in the layer was calculated to be 0.05 W kg^{-1}, in good agreement with previous estimates.

J. Geophys. Res., A, Paper 4A0699

0410 Absorption and Scattering of radiation
OXYGEN ABSORPTION CROSS SECTIONS IN THE HERZBERG CONTINUUM AND BETWEEN 206 AND 327 K
H. S. Johnston, M. Paige, and F. Yao (Department of Chemistry, University of California and Materials and Molecular Research Division, Lawrence Berkeley Laboratory, Berkeley, California 94720)

The ultraviolet absorption cross sections for molecular oxygen have been determined for wavelengths between 205 and 225 nm, for temperatures between 206 and 327 K, and at a pressure from 100 to 750 torr. No temperature effect on the O_2 cross sections was observed in the Herzberg continuum. It was necessary to separate the extremely weak O_2 absorption from the stronger collision-induced absorption. These experimental data and similar data by others were interpreted in terms of a theoretical expression for the shape of the Herzberg continuum absorption spectrum. The O_2 absorption cross sections are in good agreement with the values measured in the stratosphere by Herman and Mentall [1982]. (oxygen, cross-sections.)

J. Geophys. Res., D, Paper 4D0993

Electromagnetics

6780 Scattering
COHERENT ELECTROMAGNETIC WAVE PROPAGATION THROUGH RANDOMLY DISTRIBUTED AND ORIENTED PAIR-CORRELATED DIELECTRIC SCATTERERS
V.N. Varadan (Wave Propagation Laboratory, The Pennsylvania State University, University Park, PA 16802, U.S.A.) T.Ma and V.V. Varadan

Coherent attenuation of electromagnetic waves by randomly distributed and oriented pair-correlated dielectric scatterers is studied as a function of frequency and volume concentration of scatterers. Average frequency dependent dielectric properties are also studied. The results indicate that the attenuation and hence the effective properties differ considerably from those of aligned scatterers.

Rad Sci., Paper RS0910

6799 (General) Microwave Imaging
PROSPECTS FOR THREE-DIMENSIONAL PROJECTIVE AND TOMOGRAPHIC IMAGING RADAR NETWORKS
N. H. Farhat (Moore School of Electrical Engineering, University of Pennsylvania, Philadelphia, PA 19104), C. L. Werner (Jet Propulsion Laboratory, Pasadena, CA 91109), and T. H. Chu (RCA David Sarnoff Research Center, Princeton, N. J. 08540).

Results of a study demonstrating the feasibility of broad band and speckle-free projective imaging of a complex shaped scattering object in the 6-17 GHz range with centimeter resolution are presented. We show how angular, spectral, and polarization diversities can be combined in the data acquisition process, with a unique target-derived reference technique to access the three-dimensional Fourier space of the scatterer cost-effectively. Image retrieval algorithms, based on the projection slice theorem and knowledge of object symmetry, are utilized in obtaining images of a model aircraft with near optical resolution. The implications for high-resolution three-dimensional tomographic imaging radar networks are discussed. (tomography, inverse scattering).

Rad. Sci., Paper 4S0664

Exploration Geophysics

0440 Magnetic and electrical methods
MAGNETOTELLURIC RESPONSES OF THREE-DIMENSIONAL BODIES IN LAYERED EARTHS
Phillip E. Wannamaker (Earth Science Laboratory, University of Utah Research Institute, 391 C Chipeta Way, Salt Lake City, UT 84108) Gerald W. Hohmann, Stanley H. Ward

The electromagnetic fields scattered by a three-dimensional (3-D) inhomogeneity in the earth are affected strongly by boundary charges. Boundary charges cause normalized electric field magnitudes, and thus tensor magnetotelluric (MT) apparent resistivities, to remain anomalous as frequency approaches zero. However, these E-field distortions below certain frequencies are essentially in-phase with the incident electric field. Moreover, normalized secondary magnetic field amplitudes over a body ultimately decline in proportion to the plane-wave impedance of the layered host. It follows that tipper element magnitudes and all MT function phases become minimally affected at low frequencies by an inhomogeneity.

Resistivity structure in nature is a collection of inhomogeneities of various scales, and the small structures in this collection can have MT responses as strong locally as those of the large structures. Hence, any telluric distortion in overlying small-scale extraneous structure can be superimposed to arbitrarily low frequencies upon the apparent resistivities of buried targets. On the other hand, the MT responses of small and large bodies have frequency dependencies that are separated approximately as the square of the geometric scale factor distinguishing the different bodies. Therefore, tipper element magnitudes as well as the phase of all MT functions due to small-scale extraneous structure will be limited to high frequencies, so that one may "see through" such structure with these functions to target responses occurring at lower frequencies.

About a 3-D conductive body near the surface, interpretation using 1-D or 2-D TE modeling routines of the apparent resistivity and impedance phase identified as transverse electric (TE) can imply false low resistivities at depth. This is because these routines do not account for the effects of boundary charges. Furthermore, 3-D bodies in typical layered hosts, with layer resistivities that increase with depth in the upper several kilometers, are even less amenable to 2-D TE interpretation than are similar 3-D bodies in uniform half-spaces. However, centrally located profiles across geometrically regular, elongate 3-D prisms may be modeled accurately with a 2-D transverse magnetic (TM) algorithm, which implicitly includes boundary charges in its formulation. To defining apparent resistivity and impedance phase for TM modeling of such bodies, we recommend a fixed coordinate system derived using tipper-strike, calculated at the frequency for which tipper magnitude due to the inhomogeneity of interest is large relative to that due to any nearby extraneous structure.

GEOPHYSICS, VOL. 49, NO. 9

0920 Magnetic and electrical methods
THE BEHAVIOR OF THE APPARENT RESISTIVITY PHASE SPECTRUM IN THE CASE OF A POLARIZABLE PRISM IN AN UNPOLARIZABLE HALF-SPACE
Seikei Soininen (The Geological Survey of Finland, Geophysics Department, SF-02150 Espoo 15, Finland)

In the application of the broadband induced polarization method, it is necessary to know how a petrophysical resistivity spectrum is transformed into an apparent spectrum measured in the field. Investigated in the present work was the forming of an apparent spectrum in the case of a polarizable three-dimensional prism embedded in an unpolarizable half-space for gradient and dipole-dipole arrays. The computations were done numerically using the integral equation technique. The frequency dependence of the resistivity of the prism was depicted by means of the Cole-Cole dispersion model.

With this simple model geometry, the phase spectra of apparent resistivity resemble quite closely in functional form the original petrophysical phase spectrum of the Cole-Cole dispersion model. The apparent spectra have shifted on the log-log scale downward, owing to geometric attenuation, and toward lower frequencies.

The apparent Cole-Cole parameters have been inverted from the apparent spectra. The apparent chargeability is generally noticeably smaller, owing to the geometric attenuation, than the chargeability of the original petrophysical spectrum. The apparent frequency dependence, on the other hand, is very close to the value of the original frequency dependence. The shift of the apparent phase spectrum toward lower frequencies partly compensates for the decrease in the apparent time constant caused by attenuation of the spectrum. The apparent time constant is thus close to the true time constant of the petrophysical spectrum. It is therefore possible in principle to obtain by direct inversion from an apparent spectrum [illegible] the parameters of the petrophysical spectrum.

GEOPHYSICS, VOL. 49, NO. 9

0948 Magnetic and electrical methods
THE USE OF [illegible] IN ELECTROMAGNETIC MODELING
C. Z. Tarlowski (CSIRO Division of Mineral Physics, P.O. Box 136, North Ryde, N.S.W. 2113, Australia) A. P. Raiche, and M. Nabighian

[illegible]

GEOPHYSICS, VOL. 49, NO. 9

0936 Seismic methods
VELOCITY ANISOTROPY OF SHALES AND DEPTH ESTIMATION IN THE NORTH SEA BASIN
N. C. Banik (Gulf Research and Development Company, P.O. Box 37048, Houston, TX 77236)

[illegible]

GEOPHYSICS, VOL. 49, NO. 9

0930 Seismic methods
TRANSIENT REPRESENTATION OF THE SOMMERFELD-WEYL INTEGRAL WITH APPLICATION TO THE POINT SOURCE RESPONSE FROM A PLANAR ACOUSTIC INTERFACE
Martin Tygel (Universidade Federal da Bahia, Instituto de Geociências, Rua Caetano Moura 123, Federação, Salvador, Bahia, Brazil) Peter Hubral

[illegible]

GEOPHYSICS, VOL. 49, NO. 9

0930 Seismic methods
THE ROLE AND APPLICATION OF ENTROPY TERMS FOR ACOUSTIC WAVE MODELING BY THE FINITE-DIFFERENCE METHOD
[illegible]

GEOPHYSICS, VOL. 49, NO. 9

0930 Seismic methods
TRAVELTIME AND WAVEFRONT CURVATURE CALCULATIONS IN THREE-DIMENSIONAL INHOMOGENEOUS LAYERED MEDIA WITH CURVED INTERFACES
R. Gjøystdal (NTNF/NORSAR, Post Box 51, N-2007 Kjeller, Norway) J. E. Reinhardsen, and B. Ursin

[illegible]

GEOPHYSICS, VOL. 49, NO. 9

Geochemistry

1420 Chemistry of bodies of water
NITRATE [illegible]
H.F. Hemond (Dept. of Civil Engineering, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139), [illegible]

[illegible]

Water Resour. Res., Paper 4W0860

1499 Geochemistry, General or miscellaneous
[illegible]

Water Resour. Res., Paper 4W0846

Geodesy and Gravity

1940 Rotational Variations
TIDAL TERMS IN UNIVERSAL TIME: EFFECTS OF ZONAL WINDS AND MANTLE ANELASTICITY
J.B. Merriam (Department of Earth Sciences, Memorial University of Newfoundland, St. John's, Newfoundland, A1B 3X7)

[illegible]

J. Geophys. Res., B, Paper 4B0683

Geomagnetism and Paleomagnetism

1560 Time variations, paleomagnetism
TECTONIC ROTATIONS WITHIN THE RIO GRANDE RIFT: EVIDENCE FROM PALEOMAGNETIC STUDIES
Laurie L. Brown (Dept. of Geology and Geography, Univ. of Massachusetts, Amherst, MA 01003) and Matthew P. Golombek

Paleomagnetic studies on Oligocene-Pliocene volcanic rocks from the Española basin of the Rio Grande rift, New Mexico, reveal directions discordant from the expected mean direction for North America. The Peñas Canyon Formation, Tschicoma Formation and Lobato basalt, all sampled in the Jemez Mountains west of the Pajarito fault zone, have mean declinations east of the expected mean. The Cerros del Rio volcanics, lying east of the Pajarito fault zone, have a westerly declination. Combined with published data on the Santa Fe Group sediments east of the fault zone, and the Valles rhyolite, west of the fault zone, distinct rotations of the two areas are evident. The western block has rotated clockwise 12°, while the eastern block shows 16° of counter-clockwise motion. Differential rotations of 25°-30° are calculated between the two blocks; 5°/m.y. is the minimum differential rotation for the past 5 Ma. Geologic explanations for these rotations include the opening of the Rio Grande rift in response to clockwise rotation of the Colorado Plateau and significant left slip along the Rio Grande rift. (Tectonics, volcanics, Rio Grande rift)

J. Geophys. Res., B, Paper 4B0991

1599 General (vertical indicators of dredged basalts)
SEGREGATION VESICLES OF OCEAN FLOOR BASALTS (1).
T. Bideau (Centre Océanologique de Bretagne, BP 337, 29273 Brest Cedex, France), P. Provot and A. Lecaille.

Pillow-lava samples dredged from the rift valley of the Atlantic Ridge (FAMOUS area) are oriented according to their cooling position on the sea floor (vertical) by the segregation vesicle technique (Bideau et al., 1977). The scattering of data is discussed in terms of statistics and petrological observation. Criteria for selecting suitable samples are presented. The use of segregation vesicles as indicators of the vertical orientation of the rocks at the time of magnetization is critically reconsidered. (magnetic inclination, pillow-lavas, orientation of lava flows).

J. Geophys. Res., B, Paper 4B0585

Hydrology

3171 Soil Moisture
IN-SITU ESTIMATION OF HYDRAULIC CONDUCTIVITY USING SIMPLIFIED METHODS
A. J. Jones and R. J. Wagenet (Department of Agronomy, Cornell University, Ithaca, NY, 14853)

Five simplified methods of estimating the relationship between hydraulic conductivity (K) and water content (θ) were compared. Redistribution of water following constant rate infiltration (steady state) was monitored for a ten day period at 196 locations and seven depths at each location within a 5000 m² fallow sandy loam field. All simplified methods assumed a unit hydraulic gradient during redistribution and an exponential relationship between K and θ of the form $K(\theta) = K_o \exp[\beta(\theta - \theta_o)]$. Water content data were used to calculate K_o and β by each method at each depth and location. Soil-water flux was estimated for selected depths using appropriate mean and variance values of K_o and β for the field. It was found that estimation of the degree of spatial variation in soil-water flux is dependent upon the method used to characterize the K(θ) relationship only if the mean and variance of the flux are being estimated at short times following steady state, nearly saturated conditions. Estimates of the flux for longer times is not greatly influenced by choice of method. The spatial dependence of K(θ) measured by these methods is also discussed.

Water Resour. Res., Paper 4W0918

3190 Hydrology (Instruments and Techniques)
CONTROLLABILITY CONDITIONS FOR RESERVOIR FLOOD CONTROL SYSTEMS WITH APPLICATIONS
Jan L. Marion (Centre for Statistics and Operations Research, Free University of Brussels, Brussels, Belgium)

A number of theoretical results are presented concerning the necessary and sufficient conditions under which there exists a regulation for a multi-reservoir flood control system with given deterministic inflows, such that no flooding occurs at a flood damage center situated downstream. These so-called controllability conditions have a very simple form for a large variety of multireservoir systems; they can be reduced to the existence of a one-flood system. It is then suggested how these findings can be used as an aid in the planning and operation of structural flood control systems. A practical example is given with numerical results that are impossible to obtain without the use of the theoretical findings on controllability.

Water Resour. Res., Paper 4W0938

3199 General (Interactive Modeling)
INTERACTIVE DATA MANAGEMENT FOR RESOURCE PLANNING AND ANALYSIS
D.P. Loucks (School of Civil and Environmental Engineering, Cornell University, Ithaca, New York 14853), M.R. Taylor and P.N. French

Since the mid-1970's, a number of research projects at Cornell University have focused on the development and application of interactive models and computer programs for studying water resources and environmental management problems. These models and programs have been adapted for use with computer graphics display devices. This interactive computer-aided planning system has been designed to facilitate data input, editing and display; model building and solution; and analysis and synthesis of alternative resource management plans or policies. This paper discusses the approaches taken for managing and displaying data that are needed for, and derived from, this interactive modeling system. Several applications are presented and some conclusions on how such systems might be developed or expanded in the future are proposed.

Water Resour. Res., Paper 4W0978

3199 (Interactive Modeling)
A MODULAR INTERACTIVE SIMULATION SYSTEM FOR EUTROPHICATION AND REGIONAL DEVELOPMENT
Kurt Fedra (International Institute for Applied Systems Analysis, Laxenburg, Austria)

An interactive, policy-oriented simulation and information system including videographics is introduced. The system is designed as a tool for learning about large, complex, regional environmental systems. A high degree of flexibility is achieved through the use of simple modules, describing elements of the system at various levels of detail and resolution. Background information from a historical database drives the default evolution of the system. Alternative courses of action can be simulated at various hierarchical levels of management or policymaking. An interactive, dialogue-oriented, user-interface controls the simulations and the display of results, including videographics with geographical or statistical information. The approach is discussed in terms of a pilot application project, dealing with a lake/watershed system having conflicts between water quality and regional development goals.

Water Resour. Res, Paper 4W0974

3199 General (Interactive Modeling)
INTERACTIVE COMPUTER TECHNOLOGY FOR PLANNING AND POLICY MODELING
Kurt Fedra (International Institute for Applied Systems Analysis, Laxenburg, Austria), D. P. Loucks

This paper speculates on the potential impacts of our increasing access to and use of computer technology and communication, especially with respect to planning and policy making. The focus of the discussion is on the interaction between the users of this expanding technology, and the technology itself. Those involved in its development, whether it be the hardware or software of this technology, are in a position to make substantial contributions toward a more effective use of the models, and their data bases, by planners and policy analysts. Specific features of the technology and of environmental planning and policy making processes are examined to identify where and how interactive computer-based models and associated hardware can best serve individuals, their organizations or institutions. Finally, the necessary conditions for the successful implementation of such tools and methods are identified.

Water Resour. Res., Paper 4W0971

3100 General (Interactive Modeling)
INTERACTIVE WATER RESOURCES MODELING AND MODEL USE: AN OVERVIEW
D. P. Loucks (School of Civil and Environmental Engineering, Cornell University, Ithaca, New York), J. Kindler and K. Fedra

This serves as an introduction for the following sequence of five papers on interactive water resources and environmental management, policy modeling and model use. We review some important shortcomings of many management and policy models and argue for improved human-computer-model interaction and communication. This interaction can lead to more effective model use which in turn should facilitate the exploration, analysis and synthesis of alternative designs, plans and policies by those directly involved in the planning, management or policy making process. Potential advantages of interactive modeling and model use, as well as some problems and research needs, are discussed.

Water Resour. Res., Paper 4W0977

3199 General (Interactive Modeling)
INTERACTIVE COMPUTER MODELING FOR POLICY ANALYSIS, THE FLOOD HAZARD PROBLEM
Howard Kunreuther and Louis Miller (Department of Decision Sciences, The Wharton School University of Pennsylvania, Philadelphia, PA 19104)

This paper discusses an interactive modeling system to support policy analysis for dealing with flood hazards. Policy analysis in this area is complex due to numerous stakeholders with varying concerns, the variety of scenarios that might be considered, and alternative policy options. These conditions require that a modeling system be flexible and support users in a variety of ways. The system should be viewed as a decision aid rather than a burden. The modeling [illegible] these goals for microanalytic models that deal with samples of homeowners in a flood-prone community.

Water Resour. Res., Paper 4W0976

3199 General (Interactive Modeling)
INTERACTIVE COMPUTER MODELING, MONITORING AND CONTROL OF MELBOURNE'S WATER SUPPLY SYSTEM
G.O. Cosfriff, P.E. Forte, M.A. Kennedy, J.V. Russell, P.D. Smith, and A.K. West (Melbourne and Metropolitan Board of Works, Melbourne, Victoria, Australia)

This paper describes the application of a network model to Melbourne's water supply system, including the implementation of telemetering and computer graphics techniques. Examples demonstrating the application of color graphics to different parts of the system are given together with a discussion of the present integrated modelling, operation and telemetry capability. The models will be continually modified and improved as both new systems are added to Melbourne's water supply system and greater knowledge of the existing system is gained.

The implementation and use of the 24-hour network simulation program by the Board has already resulted in a current savings in excess of $30 million. This is more than 6 times the total cost of the modeling and telemetry system. Future benefits are expected to add to this savings.

Water Resour. Res., Paper 4W0974

Meteorology

3715
NO MEASUREMENTS IN CLEAN CONTINENTAL AIR AND ANALYSIS OF THE CONTRIBUTING METEOROLOGY
M.J. Bollinger, C.J. Hahn, D.D. Parrish, P.C. Murphy, D.L. Albritton and F.C. Fehsenfeld (Aeronomy Laboratory, National Oceanic and Atmospheric Administration, Boulder, CO, 80303)

Measurements have been made of NO_x ($NO + NO_2$) at a site located in the Colorado mountains. These measurements revealed periods of exceptionally low NO_x mixing ratios. During these episodes the NO_x mixing ratio dropped below 20 parts per trillion by volume for extended periods. These episodes are characterized by synoptic meteorological conditions in which air transported to this site is isolated from contamination by ground-level sources of NO_x.

J. Geophys. Res., D, Paper 4D0974

3740 Climatology
SOME ASPECTS OF THE INTERANNUAL VARIATION OF MEAN MONTHLY SEA LEVEL PRESSURE ON THE SOUTHERN HEMISPHERE
Kingtse C. Mo (M/A COM Sigma Data Services Corp., Goddard Space Flight Center, NASA Greenbelt, MD 20771), Harry van Loon (National Center for Atmospheric Research, Boulder, CO, 80307)

We calculate the seasonal changes which are largely associated with the half yearly wave, autocorrelation functions, and the mean planetary waves in the monthly mean sea level pressure from two data sources. One covers the period from 1951 to 1968 from the South African Weather Bureau, and the other covers the period from 1972 to 1980 from the Australian Bureau of Meteorology. Thirty years of data from stations over the Southern Hemisphere are used to assess the reliability of the differences between the two periods which the grid-point data show.

These differences are especially large over the Atlantic Ocean and the Pacific Ocean. The station data confirm the changes between the two periods and thus the observed differences in the mean waves, which are especially large for wave number three.

J. Geophys. Res., D, Paper 4D0942

3745 Gravity waves, Tides, and Compressional waves
LONG PERIOD VARIATIONS IN THE SOLAR SEMIDIURNAL ATMOSPHERIC TIDE
Kevin Hamilton (Department of Oceanography, University of British Columbia, Vancouver, B.C., Canada V6T 1W5); Rolando R. Garcia (National Center for Atmospheric Research, P.O. Box 3000, Boulder, CO 80307)

A seventy-nine year record (1866-1944) of hourly surface pressure observations at Batavia (6.2°S, 106.8°E) was analyzed to detect systematic long period variations in the solar semidiurnal barometric oscillation ($S_2(p)$). Evidence was found for a quasi-biennial oscillation (QBO) in $S_2(p)$ throughout the latter half of the record (1905-1944). This is attributed to the effect of the familiar QBO of the tropical stratospheric mean winds and temperatures on the solar semidiurnal tide. The results thus suggest that the stratospheric QBO itself has been proceeding in something like its present form since at least the beginning of the twentieth century.

Some theoretical calculations were performed of the change expected in $S_2(p)$ between the minimum and maximum in the sunspot cycle employing different published estimates of the solar ultraviolet flux variability. It is clear from the present $S_2(p)$ observations that, if there is any regular eleven year cycle in the solar ultraviolet flux at wavelengths ~200 nm, then it must be much smaller than some of the published estimates based on direct flux measurements. However, for periods around two individual sunspot minima (1867 and 1913) there are changes in the Batavia $S_2(p)$ consistent with a large drop in solar ultraviolet output.

J. Geophys. Res., D, Paper 4D0992

3760 Storms (Meteorology)
LIGHTNING PHENOMENOLOGY IN THE TAMPA BAY AREA
R. W. Pechar (Department of Electrical Engineering, University of Florida, Gainesville, Florida, 32611), M. A. Uman and E. P. Krider, Jr.

A lightning locating system employing two wideband, gated magnetic direction-finders was used to study the negative cloud-to-ground lightning in 11 storms which occurred on eight days during August, 1979, in the Tampa Bay area of Florida. [illegible] duration in minutes, δ, and number of ground flashes, N_F, for single and multiple-peak storms can be described by $\log_{10} N_F = 0.0140\delta + 1.2$.

J. Geophys. Res., D, Paper 4D0995

Oceanography

4704 Boundary layer and exchange processes
ISOLATION DURING STREX PART 1: COMPARISONS BETWEEN SURFACE MEASUREMENTS AND SATELLITE ESTIMATES
C. Gautier (California Space Institute, A-021, Scripps Institution of Oceanography, University of California San Diego, La Jolla, CA 92093) K. B. Katsaros

Comparison between measurements of insolation from pyranometers mounted on ships and estimates from satellite visible measurements during STREX are presented. In general, for both hourly and daily insolation values, the comparison is quite favorable. The root mean square (r.m.s.) difference between the two measurements of daily insolation was about 11 watts m^{-2}. From a detailed analysis of the errors and measurement discrepancies, it was found that a large part of the difference between the two estimates of insolation could be due to inaccuracies in the surface measurements. Intercomparison during periods of radio interference and [illegible] comparisons between time-averaged insolation values over periods of about 10 days and limited statistical analysis of the pyranometric time series suggest that, on that time scale, the accuracy of the satellite estimates is of the order of 4 watt m^{-2}. Large-scale insolation fields derived from satellite during STREX will be presented in the companion paper (Gautier and Katsaros, 1984).

J. Geophys. Res., C, Paper 4C0391

4711 (Island Wakes)
ISLAND WAKES IN SHALLOW COASTAL WATERS
E. Wolanski (Australian Institute of Marine Science, Townsville, Queensland 4810, Australia), J. Imberger and M.L. Heron

Rattray Island, north-east Australia, is 1.5 km long, 100 m wide and lies in well mixed water approximately 15 m deep. Its long axis is inclined at about 60° into the direction of the dominant semi-diurnal tidal current. The length of the wake in the lee of the island, as documented by aerial photographs and satellite imagery, appears to equal that of the wake behind a flat plate in a two-dimensional flow at a Reynolds number of about 10. However, current metering, drogue measurement and temperature mapping indicate wake velocities much greater than would be consistent with such a simple low Reynolds number model. Further, estimates of the turbulent eddy coefficient suggest an effective Reynolds number in the vicinity of 10^3. To reconcile these observational differences and to explain the observed upwelling in the core of the wake an Ekman pumping model is proposed. It is postulated that the Ekman benthic boundary layer driven by rotation in the wake allows the vertical vorticity introduced into the water at the tip of the island at the point of separation, to be negated by the vorticity of opposite sign introduced at the bottom. Further, it is shown that a large fraction of the kinetic energy of the upstream flow facing the island is used to drive the wake eddies leading to the conclusion that the trapping of water in the lee of islands greatly increases head losses on continental shelves with numerous islands, coral reefs and rock outcrops.

J. Geophys. Res., C, Paper 4C0359

4730 Oceanography (Internal waves)
ON THE ELECTROMAGNETIC FIELDS INDUCED BY OCEANIC INTERNAL WAVES
Alan D. Chave (Institute of Geophysics and Planetary Physics, Scripps Institution of Oceanography, University of California, San Diego)

Model spectra for the electric and magnetic fields induced by oceanic internal waves are obtained by combining Green function solutions to the two electromagnetic modal equations with the Garrett-Munk kinematic description of the internal wave field. The poloidal magnetic mode is dominant at frequencies above 3f, where f is the local Coriolis frequency, and self and mutual induction are two important over this range. The toroidal magnetic mode is increasingly important at frequencies below 3f and is sensitive to the conductivity structure below the seafloor for near-inertial frequencies. The motional electric field is shown to be largely a measure of the local velocity field at high frequencies. The vertical electric field is sensitive to the horizontal velocity field, while the horizontal electric field primarily reflects the vertical velocity field and is quite small at the sea-earth and sea-air interfaces. The magnetic field is a measure of the spatially averaged velocity field and is dominated by the poloidal magnetic mode. Electromagnetic boundary effects reduce the horizontal magnetic spectrum by decades at the seafloor and sea surface. At the seafloor and sea surface, internal wave-induced magnetic fields are within an order of magnitude of their externally induced counterparts, while in the ocean's interior internal waves are probably the largest source of magnetic signals in the period range one day to one hour. The internal wave-induced electric field is not measurable except in the vertical component.

J. Geophys. Res., C, Paper 4C0893

4765 Tides
A SIMPLE MODEL OF THE RELATION BETWEEN TIDAL QUALITY AND DISSIPATION
George W. Platzman (Department of the Geophysical Sciences, University of Chicago, Chicago IL 60637)

The parametric relation between output quality and dissipation in a one-dimensional ocean with radiative dissipation is shown to be qualitatively and quantitatively similar to the relation derived numerically by synthesis of the world-ocean tide from normal modes. The relation indicates that the equivalent oscillator is near resonance at its fundamental frequency. (tides, tidal dissipation).

J. Geophys. Res., C, Paper 4C1004